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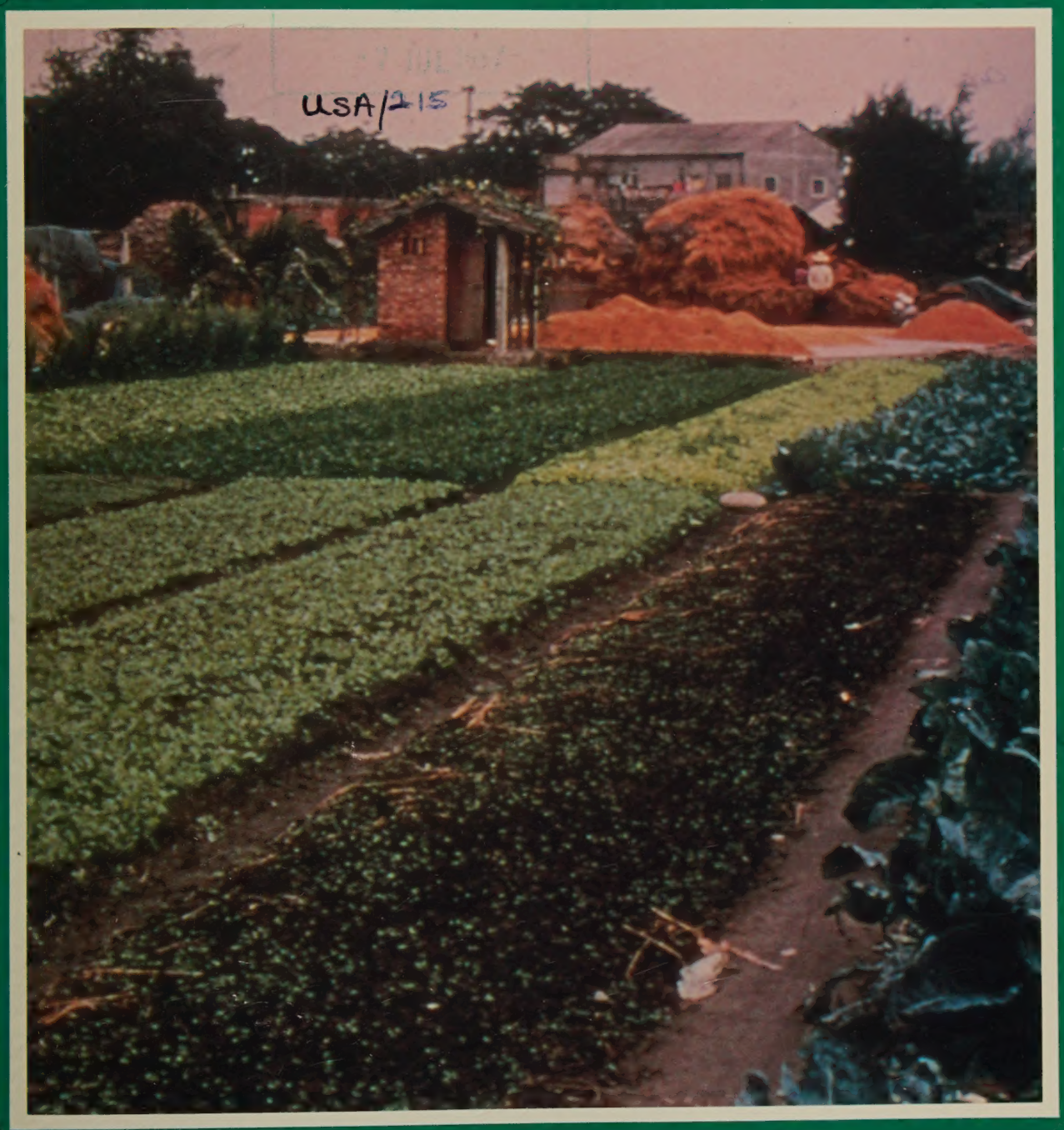

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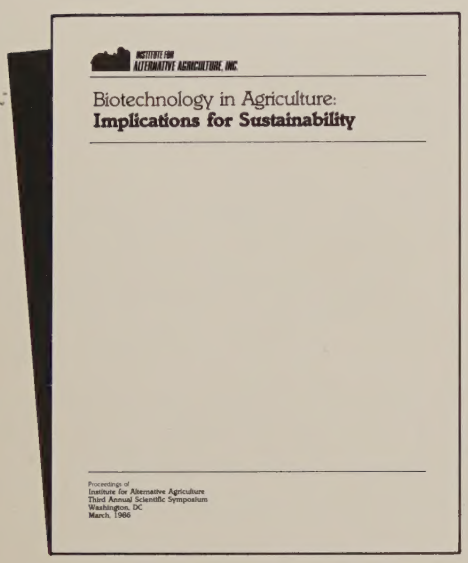

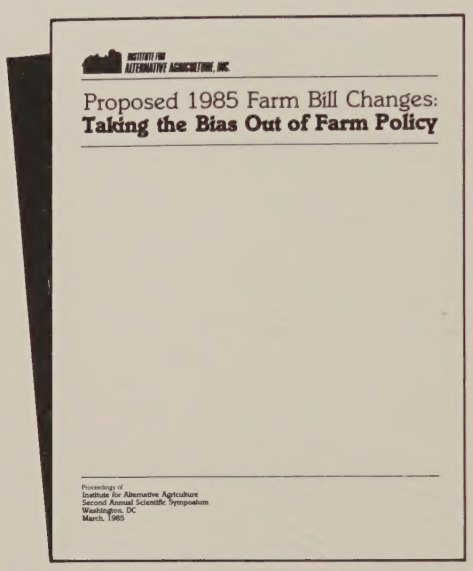

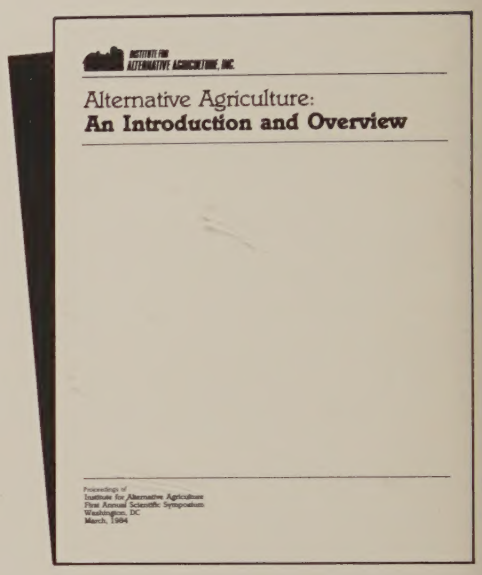

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The Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low-cost, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a 12-member Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Funds should be appropriated now for agricultural productivity research

Adding the agriculture productivity subtitle to Title 14 of the 1985 Food Security Act was a legislative breakthrough made possible by broad Congressional interest and support. The inclusion of Subtitle C in the research section gave alternative agriculture the official recognition and credibility that comes with being written into a major multi-year farm bill.

This action was especially significant because it was the first taken by Congress to implement USDA's 1980 report and recommendations on organic farming. This widely-circulated report concluded that research and education programs should be developed and implemented to address the needs and problems of organic farmers and to enhance the success of conventional farmers who may wish to shift toward organic farming systems and technologies.

Unfortunately this balanced and constructive report had little impact on official USDA policy. It has, however, had considerable influence in changing attitudes in other public agencies and institutions, including many land grant universities. It gave much-needed scientific and economic credibility to organic farming, which was described recently in an Office of Technology Assessment report as an important emerging agricultural technology.

This legislation, guided by James Weaver (D-OR) in the House and Patrick Leahy (D-VT) in the Senate, also won over the agricultural establishment in Congress. Chairman Kika de la Garza (D-TX) of the House Agriculture Committee has called it "a very small first step to bring coordination to an area that hopefully can be the salvation of American and world agriculture in the years to come." The first time the legislation passed the House, he told its members in remarks on the floor that they would "not have a more important bill on agriculture this year."

By 1985 the proposal had gained so much ground that it passed without a roll call. Four national farm organizations were pushing it by that time, most urban representatives supported it, and it had the attention and backing of a long list of national environmental, church, and consumer groups. Subtitle C has all the earmarks of an idea whose time has come.

Budget problem encountered

Unfortunately this legislation became law at a time of severe budget restraint. Although the funding needed for agriculture productivity research and education activities is authorized, there is no assurance that the $2 million that has been requested by Congressional supporters to get USDA started on these programs will actually be appropriated. All new legislative initiatives have rough going due to the continuing budget crunch and that appears to be the prognosis for Subti C at this time.

We believe Congress should set budget considerations asi and make an exception in regard to implementing the pr ductivity provisions of the farm bill. It is an extremely co effective way to do something about high input costs a related economic problems in agriculture. The amount money involved is extremely small and the need to initiate modest research and education effort is at least six yea overdue.

According to the scientists who wrote the 1980 USI report, "much can be learned from a holistic research eff to investigate the organic system of farming, its mechanisr interactions, principles, and potential benefits to agricultu both at home and abroad." The report further stressed th a complete understanding of these low-input systems of p duction would require a long-term, coordinated, interdis plinary program. Subtitle C was designed with these speci objectives in mind.

Farm costs reduced

Agriculture and farm structure trends over the past years have only served to underscore the critically import nature of such an effort. The urgent need to cut farm p duction costs alone justifies full funding for Subtitle C. I imperative that all farming systems be investigated that c turn a profit for the individual farmer while simultaneou reducing huge government subsidy payments. The legur based cropping systems and other technologies characteris of organic farms may help point the way toward achievin measure of both economic and environmental stability in riculture. Given the growing problems that continue to plag conventional, chemical-intensive agriculture, shouldn't agricultural research and education institutions now be i tiating long-term studies of alternative systems and their tential for restoring balance, profits, and sustainability agriculture?

At the very least, funding should be provided for the p liminary non-research provisions of the legislation. That cludes a detailed and comprehensive information study inventory and classify all relevant studies related to agricult productivity and establishment of the panel of public expe who would make decisions about appropriate research pr ects.

If that preliminary work could be completed during coming year, it would be much easier to push ahead w specific on-farm research projects that are the most import aspects of the authorized agriculture productivity activiti

Bacterial solubilization of mineral phosphates: Historical perspective and future prospects

Alan H. Goldstein

Abstract. *Maximum crop yields require sufficient phosphorus fertilization. Only phosphate in a soluble ionic form (Pi) is effective as a mineral nutrient. Current fertilizer technology supplies the soil solution with Pi via the application of large amounts of phosphate salts. Problems with this technology include energy-intensive production processes, the need for large scale mechanical application with associated environmental consequences, and reprecipitation of the phosphate into insoluble mineral complexes. It has been estimated that in some soils up to 75% of applied phosphate fertilizer may be lost to the plant because of mineral phase reprecipitation. Many approaches, ranging from cultural practices to biological inoculants such as mycorrhizal fungi, are being employed to enhance P-use efficiency. One area that is currently under-investigated is the ability of certain types of bacteria to solubilize mineral and organic phosphates. A review of the literature in the area of bacterial phosphate solubilization confirms that this trait is displayed by a wide range of bacteria. The phosphate starvation inducible (PSI) organic phosphate-solubilizing capability of E. coli is a component of a coordinately regulated gene system: the pho regulon. It has long been known that bacteria are also capable of solubilizing mineral phosphates such as hydroxyapatite. To date there has been no systematic study of the genetics of this phenomenon. Data from my laboratory indicate that the bacterial mineral phosphate-solubilizing (MPS) trait is regulated by the external level of Pi. This conclusion is supported by results obtained from several types of molecular genetic studies. It is proposed that bacteria have mineral phosphate solubilizing (mps) genes. The potential agronomic applications of bacterial mineral and organic P solubilizing systems are discussed.*

Phosphorus fertilizers, soil fertility, and plant growth

Maximum agricultural yield may be obtained only when there is sufficient P available to the plant. This element is essential for virtually all major metabolic processes in plant growth and development. Phosphorus is considered a macronutrient because of its percent contribution to plant biomass. This creates a paradox with major agronomic implications since the phosphate form of P is one of the least soluble of the mineral nutrient ions in the soil. In fact, the level of P in the solution phase of naturally occurring soils is often below those of many "micronutrients" (Epstein, 1972; Fried and Broeshart, 1967). All major nutrient ions except P are normally present at concentrations from 10^{-3} to 10^{-4}M. Phosphates are usually lowest in concentration, commonly in the range of 10^{-6}M. Ozanne (1980) has concluded that in natural ecosystems P is usually the element limiting plant growth due to its low availability. Therefore, it is not surprising that most higher plants have evolved highly efficient mechanisms for absorbing P from very dilute solutions. Many crop plants can achieve maximum growth rates and yields in solution culture at 0.03 mM(1 ppm) P or less (Arnon, 1953; Ozanne, 1980). Even this impressive capability, however, is not enough to allow for maximum agronomic productivity without the addition of P fertilizer.

Most P fertilizers in use today are made by processes involving the acidulation of phosphate rock and are largely soluble in aqueous solution (Fried and Broeshart, 1967; Horwitz, 1980). These include NH_4, K, and Na orthophosphates; several forms based on monocalcium phosphate (super, triple super and concentrated superphosphate); ammonium and urea-ammonium (poly) phosphates, and various solutions. These fertilizers are applied to the soil by various cultural methods in amounts necessary to maintain the concentrations of soluble phosphate in the soil solution above a "critical" level. This level is usually defined for a given soil by correlating the amount of extractable P (water soluble or soluble in some aqueous solution, e.g. citrate, carbonate, etc.) with growth and/or yield response for a given crop. Fertility levels that give >90% of maximum yield usually are considered critical (Ozanne, 1980).

Agronomic rates of application range from 5-40 kg P/Ha for major crop plants such as corn, soybeans, and wheat. Field tests point to a critical P level of 0.2-1.0 mM for most crop plants (Kamprath and Watson, 1980). This contrasts with a critical P level of <0.03 mM in solution culture. While competition with soil organisms lowers fertilizer efficiency, it is generally accepted that retention of phosphate in insoluble mineral complexes plays a major role in inefficient P fertilizer use in agriculture. In some soils, up to 75% of applied P may be reprecipitated into insoluble mineral forms so that farmers may be advised to apply up to four times the P requirement of the crop to overcome this.

In summary, it may be stated that the major goal of P fertilization (and therefore of P fertilizers) is to maintain the concentration of ionic phosphate in the soil solution against a free energy gradient which favors precipitation into stable and metastable inorganic compounds. Phosphate precipitated in the soil is generally of such low solubility as to be useless for agronomic production of crop plants. Current technology uses application of large amounts of

Alan H. Goldstein is Assistant Professor, Department of Plant Sciences, University of Arizona, Tucson, AZ 85721.

highly soluble phosphate salts. The short-term effect is that retention phenomena are overcome long enough for the crop to grow. Assessment of long-term effects of current fertilization methods will be more complex, involving the costs for production and application of P salts. Other considerations include environmental pollution due to erosion of soil, runoff water containing large amounts of soluble P (which exist for a short time after fertilizer application), and projected decreases in the availability of high grade ore for production of phosphate fertilizers by conventional chemical processes.

Phosphorus soil chemistry

Application of P fertilizer to the soil results in chemical reactions between phosphate, soil, and non-phosphatic fertilizer components which ultimately remove P from the solution phase, making it unavailable for plant growth (Sample et al., 1980). The types of reactions involved are varied, but the general phenomenon is called P "fixation" or "retention". The former term is not to be confused with N_2 "fixation", which causes the opposite agronomic effect.

It was proposed as early as the mid-nineteenth century that calcium carbonate and hydrous oxides of Fe and Al play paramount roles in P retention (Tisdale and Nelson, 1975). The generalized mechanisms used to describe the cause of this retention were postulated to be either precipitation or adsorption. Present-day concepts, based on extensive experimental data, provide a more detailed view of the molecular bases for P retention, involving physical adsorption, chemisorption, anion exchange, surface precipitation, and mass precipitation of discrete and/or amorphous mineral phases (Sample et al., 1980). In the most general case, anionic phosphates react with the metallic components of the weathered clay particles (especially Fe, Al and their oxides and hydrous oxides) and/or calcium.

Phosphorus distribution within the soil system

Soil P important in plant nutrition may be considered to partition into four major pools: 1) the soil solution, 2) the labile inorganic pool, 3) the nonlabile inorganic pool, and 4) the organic pool. Since P is not present to any significant extent in the gas phase, the pool distribution is within a two phase system. Interactions between these pools are governed by solid phase-soil solution relationships involving the nature of binding to (or in) the solid phase and the concentrations of phosphate associated with the two phases. It is generally considered that only labile inorganic P (i.e. phosphate held on exchange sites by weak adsorption or precipitated in ionic complexes of significant solubility) plays an important role in the short term mineral nutrition process involved in growing annual crop plants. This pool is defined operationally as being at or close to equilibrium with the soil solution.

Percentage utilization of soluble P for plant growth has often been shown experimentally to be 10% or less (Fried and Broeshart, 1967). Even under agronomic conditions (i.e. 5 to > 50 lb elemental P/Ha) there is not enough phosphate in the soil solution to support maximal plant growth for more than a few hours (Fried and Broeshart, 1967). Under steady state conditions, the soil solution is replenished through dissociation of bound phosphate from the labile inorganic pool. In an "ordinary" soil, the amount of relatively rapidly exchangeable phosphate may be 1.5 to 2.0 X 10^{-4} moles per 100 g with approximately 0.1 X 10^{-6} moles in the soil solution (Fried and Broeshart, 1967; Katznelson and Bose, 1959). Therefore, only 1/1500 to 1/2000 of the phosphate is in solution at any given time. Mass flow is essential to obtain movement over any significant distance since phosphate diffusion is limited to a few centimeters over the entire growing season even when concentration gradients are high (e.g. near a fertilizer band) (Fried and Broeshart, 1967). Because P is almost immobile in the soil in the absence of mass flow, and because mass flow removes only a minute fraction of P, agronomically useful P cycling must occur at the root/soil interface. It is in this region, also known as the rhizosphere, that effective P fertilization is accomplished.

Bacterial solubilization of insoluble mineral phase phosphate

It may be stated with certainty th only phosphorus available in solub ionic form (mainly $H_2PO_4^-$) at the ro cell plasma membrane surface will effective as a plant mineral nutrient. massive literature exists devoted to ph siochemical studies of the fate of pho phorus fertilizer materials applied to t soil under agricultural field condition These studies usually involve the app cation of a known quantity of P and t subsequent measurement of the amou of P retained in various mineral cor plexes as a function of soil paramete such as soil type, pH, water content, et Additionally, crop yield and/or grow might be measured and correlated wi the physiochemical properties of the so However, little is known about the fa tors that control the availability of pho phorus within the rhizosphere.

The prevailing agronomic philosop has been that maintenance of ionic pho phate in the soil solution above the cr ical level will provide adequate nutrition to the plant. While general true, this type of approach often has t effect of bypassing the available syster within the rhizosphere that participa in P cycling. Modern chemical fertiliz application methods can grow crops b often sacrifice the potential for great enhanced efficiency and environment safety by attempting to modify t chemical composition of the soil soluti in the root zone. On a more hopeful no a number of novel cultural techniqu and fertilizer formulations have been d veloped to increase P-use efficienc These will be discussed briefly in a la section.

An alternative to this approach volves the intensive regulation of pho phate availability within t rhizosphere. A bacterial agent acting solubilize mineral and organic pho phates could become an important co ponent of this system. The presence mineral phosphate-solubilizing mic organisms within the rhizosphere (d fined as the soil that surrounds and influenced by the roots of a plant) h often been suggested (Gerretsen, 19 Sackett et al., 1908). Recent work

ating to mycorrhizae points to the existence of a highly sophisticated symbiotic plant/fungus system which functions with respect to P mineral nutrition in a manner loosely analogous to the nitrogen-fixing dicot/*Rhizobium* association (Tinker, 1980).

In addition to the mycorrhizal association, the possibility that rhizosphere bacteria may act to make phosphate available to the plant has also been explored. The results obtained to date have been limited but encouraging. The ability to solubilize poorly soluble mineral phosphates (e.g. dicalcium phosphate or hydroxyapatite) has been shown *in vitro* for many commonly occurring soil bacteria, although *in vivo* data have generally been equivocal. However, the ecological paradox of growth-limiting amounts of soluble P in the midst of large amounts of unavailable mineralized P (even in native soils) provides a strong evolutionary basis for the development of the Mineral Phosphate Solubilizing (MPS) trait. The fact that this trait is easily demonstrated *in vitro* provides a rationale for designing bacterial P fertilizers. A comparison of current problems with and biological approaches to N and P fertilization is presented in Table 1.

Sackett et al. (1908) noted that the relationship between soil microorganisms and phosphorus was being ignored while microorganisms/soil nitrogen relationships "claimed the almost undivided attention of the soil chemist and soil bacteriologist." These workers called for an increase in research into the microbial role in the availability of soil P because "compounds...which are only slightly soluble in water...are being used in the field quite generally and with success as sources of phosphoric acid...." They asked the question: "Are microorganisms in any way associated with this solvent action?" In their studies, 36 out of 50 different bacteria isolated from soil were found to give "definite, visible solvent action" on raw bone meal and/or phosphate rock. Unfortunately, the request for increased investigation of this phenomenon appears to have gone unheeded until the late 1940's, at which time Gerretsen, in a classic study, set out to examine the influence of microorganisms on phosphate intake by the plant (Gerretsen, 1948).

While somewhat primitive by today's standards, Gerretsen's methods were quite rigorous, including reasonable (6 hours or more) sterilization times for soil/sand and the development of insoluble phosphate agar plates for visualization of phosphate solubilization by roots and microbes. Plant growth (biomass) enhancements of 72-188% and P intake increases of 79-324% were observed in unsterilized vs sterilized systems. Gerretsen himself noted that "the question arises as to what extent the better development of plants could be the result of the general activity of different groups of soil bacteria in the nonsterile soil with an increased phosphate intake as a logical consequence of better growth and expanded root system." Further experiments using sterile culture of the entire root-soil system tended to support the hypothesis that rhizosphere microorganisms play a major role in providing the plant with soluble phosphate.

Unfortunately, Gerretsen's efforts remain characteristic of the type of research conducted on bacterial P solubilization and plant growth. Major reviews of rhizobiology (e.g. Rovira and Davey, 1974; Tinker, 1980) do not cite any work involving the physiological or molecular genetics of this trait. This is not to say that there has been no work on bacterial P solubilization but rather that there have been few comprehensive efforts to correlate this phenomenon with plant growth and/or productivity and probably none on the genetic basis of the trait itself.

In 1957, Sperber (1957) attempted to elucidate the mechanism by which soil bacteria dissolve mineral phosphates. She identified organic acids produced in culture by putative MPS bacteria. Lactic, glycolic, fumaric and succinic acids were identified from various soil samples. She obtained 291 bacterial isolates, of which 184 grew on insoluble P agar (see Figure 1 for a description of this type of media). Of the 184, 84 showed digestion zones of from 1 to 10 mm in width around individual colonies. In all cases, solubilization was accompanied by a decrease in pH, the lowest value being 4.5. In a subsequent paper, Sperber (1958) demonstrated that these types of microorganisms were present in the plant rhizosphere in higher proportions than in nearby soil. Similarly, Louw and Webley (1959a) obtained over 100 isolates which "produced haloes around their colonies on dilution plates containing calcium phosphate."

Lactic and 2-ketogluconic acids were identified as potential phosphate-solubilizing agents. In a follow-up study, Louw and Webley (1959b) unsuccessfully attempted to correlate the occurrence of MPS bacteria with the rhizosphere region. Also Katznelson and Bose (1959) and Katznelson et al. (1962) attempted a similar study. Their experiments went even further, including efforts to separate rhizoplane, (defined as the external surface of the roots together with closely adhering soil particles, microorganisms, and debris), rhizosphere and non-rhizosphere bacteria.

Table 1. Comparison of Current Problems and Properties in Phosphorus and Nitrogen Fertilizer Technology.

Problem	*P fertilizers*	*Cause*	*N fertilizers*	*Cause*
Loss of 50-75% of applied nutrient	Yes	Physiochemical fixation within the soil matrix	Yes	Leaching and/or volatilization out of the root zone
Lack of cost-effective slow and/or timed released system	Yes	Present formulations too expensive	Yes	As with P
Availability of biological agent capable of transforming unavailable inorganic phase into soluble ionic phase	Yes	Several types of bacteria have been reported to solubilize insoluble phosphates	Yes	Several types of free-living nitrogen fixing microorganisms
Existence of an obligate symbiont capable of living in cell-to-cell contact with plant roots and providing mineral nutrient in exchange for reduced carbon	Yes	Numerous mycorrhizal fungi form these types of associations with almost all types of plants	Yes	The *Rhizobium* association

They concluded that bacterial isolates from the rhizoplane of wheat were more active in oxidizing glucose and alanine than those isolated from the rhizosphere and non-rhizosphere regions. As usual, a large number (1/3 of the 80 cultures from each region) of the bacteria isolated showed MPS activity at least for dicalcium phosphate. The fraction of MPS bacteria was apparently not preferentially stimulated in the rhizoplane, but metabolic intensity factors, such as glucose and alanine oxidation, were postulated to enhance the effectiveness of rhizoplane solubilization *in vivo*. In addition, the total number of MPS bacteria in the rhizoplane was 18 and 6 times higher than the number in the non-rhizosphere and rhizosphere regions respectively. These workers suggested the P solubilization was a major role for these types of bacteria. Duff and Webley (1959) proposed that 2-ketogluconic acid produced by bacteria plays an important role in weathering and solubilization of phosphate in soil.

Unfortunately, 1962 saw the arrival of "phosphobacterin" on the P biofertilizer scene. During the 1950s, phosphobacterin (a putative bacterial P biofertilizer) had become popular as a seed/soil inoculant in the Soviet Union and several eastern European countries (Tisdale and Nelson, 1975). Different types of microorganisms were applied. Russian investigators considered that growth enhancement resulted from an increase in available soil P caused by the decomposition of organic phosphorus compounds. The effectiveness of phosphobacterin was investigated by workers at the USDA (1962), who showed that a culture of *Bacillus megaterium* obtained from the USSR readily decomposed glycerophosphates. A small yield increase (7.5%) was observed with greenhouse-grown tomatoes. There was no increase in the yield of wheat. In addition, neither P concentration nor total P uptake was enhanced by phosphobacterin. Although many soils have large amounts of organic P (often 20% or more of total P) (Anderson, 1980), the complex regulation of bacterial organic P-solubilizing systems (see below) makes it improbable that these types of simple experimental approaches would be successful in achieving biological P fertilization. However, the failure of phosphobacterin increased the skepticism with which soil scientists and agronomists viewed biological approaches to P mineral nutrition in crop plants.

Through the 1960s and 1970s, research continued in P-solubilizing bacteria in the root zone of plants (Subba Rao, 1982a; 1982b). The general conclusions were the same as in previous studies: 1) a significant percent of bacteria isolated from soil have the ability to solubilize dicalcium phosphate and/or other poorly soluble mineral phase phosphates; 2) production of low molecular weight organic acids, which often accompanies phosphate solubilization, may account for the phenomenon either through acidification, Ca chelation, or both; and 3) the population of MPS bacteria is substantially higher in the rhizosphere than in the non-rhizosphere regions. However, no causal relationship between the presence of MPS bacteria and phosphate availability could be proven by any of these workers.

A significant research effort has been directed towards the use of microbial P biofertilizers, mainly in less developed countries and eastern Europe, over the past 20 years (Subba Rao, 1982a; 1982b). However, it must be kept in mind that the total effort in this area is minute when compared to the amount of work carried out in the same time period on nitrogen fixation (Subba Rao, 1982a). Given the nature of the experimental approaches described above, it is not surprising that the results obtained to date using P biofertilizers have been equivocal. Sufficient levels of P solubilization have been obtained with microbial agents in some experiments but not in others. Subba Rao (1982a; 1982b) has summarized the current state of the art in this area. Significant progress in the development of biological P fertilizers must be based on an understanding of P solubilization phenomena at the molecular genetic level, similar to the approach currently being applied to the nitrogen fixation (Nif) system.

In recent years there have been few papers in the area of bacterially mediated phosphate solubilization in the rhizosphere. In a series of papers, Moghimi and coworkers (1978a; 1978b; 1980) studied the release of phosphate fro calcium phosphates by rhizosphe products. These workers concluded th wheat plants were more efficient tha maize or pea in phosphate uptake fro hydroxyapatite. They further conclude that non-sterile wheat plants produce water-soluble rhizosphere products th released phosphate from hydroxyap tite. This solubilization was associate with a fraction containing large amoun of 2-ketogluconic acid. This compour released phosphate from hydroxyapati *in vitro*.

A subject that has received increase attention is "biosuper" (Raghu, 196 Rajan and Fox, 1973), a mixture phosphate rock, granulated sulfur, ar a sulfur oxidizing bacteria such as *Thio acillus* to create H_2SO_4 *in situ*, which, turn, reacts with the phosphate rock form a mixture of phosphoric acid, mo ocalcium phosphate (superphosphat and calcium sulfate. Rajan (1981) ar Rajan and Fox (1973) have reported e fective P fertilization under some agr nomic conditions with this syster While of potential utility, the sulfur acid pathway is apparently not utilize by most naturally occurring rhizosphe MPS bacteria.

In conclusion, one may state that t MPS capability is displayed in cultu by several types of bacteria known occur in the plant rhizosphere. The i portance of the MPS trait in nature wi respect to P cycling within the rhizo phere remains to be determined. T chemical/biochemical bases for this ph nomenon also remain to be determine Virtually nothing is known about t physiological genetics of the MPS tra particularly with regard to its inducti and regulation. The state of knowled about the mechanisms involved in t bacterial cycling of P in the rhizosphe is basically the same as it was in 19 The agronomic implications for progr in this area may be great. This is esp cially true in view of the fact that de ades of conventional P fertiliz application have left many soils wi large amounts of mineralized phospha In many cases, MPS bacteria cou "mine" the soil so that application any fertilizer P might be unnecessary several decades.

A phosphate starvation inducible (PSI) organic P-solubilizing gene system in E. coli

While little is known about the MPS trait in rhizobacteria, great progress has been made in our understanding of phosphate regulation of gene expression in bacteria, particularly in *E. coli*. The Pho regulon in *E. coli*, is composed of a group of genes which are negatively regulated by the level of orthophosphate (Pi) in the medium and activated by a positive effector, *pho* B, the product of the *pho* B gene (Torriani and Ludtke, 1985). Several of the phosphate starvation inducible (PSI) genes of the *pho* regulon act as a phosphate starvation rescue system by scavenging phosphate from organic esters and facilitating the transport of this scavenged Pi across the cell membrane (Wanner and McSharry, 1982). A number of genes are involved in PSI metabolism including *pho* A, the gene that codes for alkaline phosphatase.

Starvation for Pi results in a large increase in the amount of alkaline phosphatase excreted into the periplasmic space in strain K-12 of *E. coli* (Wanner and McSharry, 1982). Using the techniques of gene fusion, Wanner (1983) and Wanner and McSharry (1982) have shown that *pho*A gene expression is induced by Pi starvation. While a great deal remains to be learned about this system, it is clear that bacteria have evolved an organic phosphate-solubilizing system that can act as a phosphate starvation rescue mechanism. Since many soils have large amounts of organic P (Anderson, 1980), it is possible that these genes could be used as one component of a P biofertilizer system.

Do bacteria have insoluble mineral phosphate-solubilizing genes?

In view of our new understanding of the organic phosphate scavenging system discussed above, it is reasonable to postulate that bacteria may have also developed a genetic system to access the often large pool of unavailable mineral phosphates in the external environment. It has been shown by many workers that bacteria (and other microorganisms) can solubilize mineral phosphates. The question that must now be addressed is whether this trait is under genetic regulation. Certainly, the repression of the MPS trait by exogenous Pi would explain the frequent failure of applied bacteria to act as P biofertilizers under field conditions.

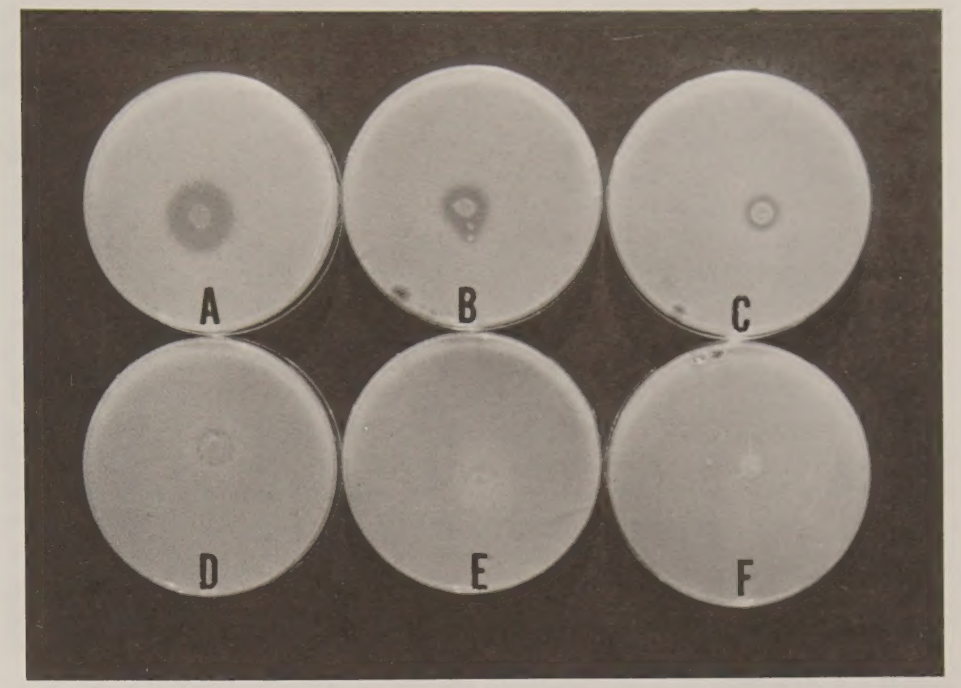

Figure 1. Repression of the mineral phosphate solubilizing (MPS) trait by increasing levels of soluble phosphate (Pi) in the medium. Equivalent numbers of *E. herbicola* were placed in the center of DCP4 overlay plates[1]. Water soluble Pi was determined by the method of Bencini et al. (1983). Pi concentrations were: A. 0.8 mM; B. 2.5 mM; C. 9.3 mM; D. 20 mM; E. 30 mM and F. 42 mM. Standard deviation of Pi concentration was 19% or less for three independent determinations with each media. The clear zones around the bacterial colonies show the area where the white crystalline dicalcium phosphate has been solubilized. The MPS trait shows repression at exogenous Pi levels above 1 mM and is completely inhibited at concentrations above 20 mM.

[1]Insoluble dicalcium phosphate (DCP) agar was prepared as follows: A minimal nutrient media consisting of 2% purified agar (Difco), 1% glucose, 0.5% ammonium chloride, 0.1% sodium chloride and 0.1% magnesium sulfate. DCP was precipitated *in situ* via addition of 10% solutions of calcium chloride and potassium phosphate in the ratios necessary to provide the precipitate plus additional exogenous Pi. The pH of the media was adjusted to 7.2 with N potassium hydroxide.

Recent work in our laboratory (Goldstein and Liu, in press) has involved efforts to characterize the regulatory properties of the MPS trait in both *E. coli* and *Erwinia herbicola*. In particular, we wanted to know whether this trait could be directly controlled by the level of soluble phosphate in the media. Figure 1 shows the results of one type of experiment. The data suggest that the MPS trait is regulated by the level of soluble phosphate in the media. When either *E. herbicola* or *E. coli* is starved for Pi in the presence of an insoluble mineral P source such as dicalcium phosphate (DCP), large zones of solubilization develop around the colony. Mineral phosphate solubilization may be turned on or off via the presence or absence of a critical (millimolar) concentration of soluble phosphate in the external media (see Figure 1). The existence of catabolite repression-like behavior for the MPS trait makes it likely that bacteria such as *E. herbicola* and *E. coli* have MPS genes.

Current attempts to identify MPS genes involve mutagenesis and recombinant DNA methods. Using both chemical and mobile genetic element mutagenesis, we have isolated a number of mutants that either lack the MPS trait or are deregulated and continue to solubilize mineral P in the presence of large amounts of exogenous Pi. Figure 2 shows the result of a mutagenesis of *E. coli* (strain HB101). Using the transposable element TN5, a mutant was isolated that could grow on minimal media containing DCP but was no longer capable of DCP solubilization even under Pi starvation conditions. It is possible that this type of mutant is deregulated in the phosphate specific transport (pst)

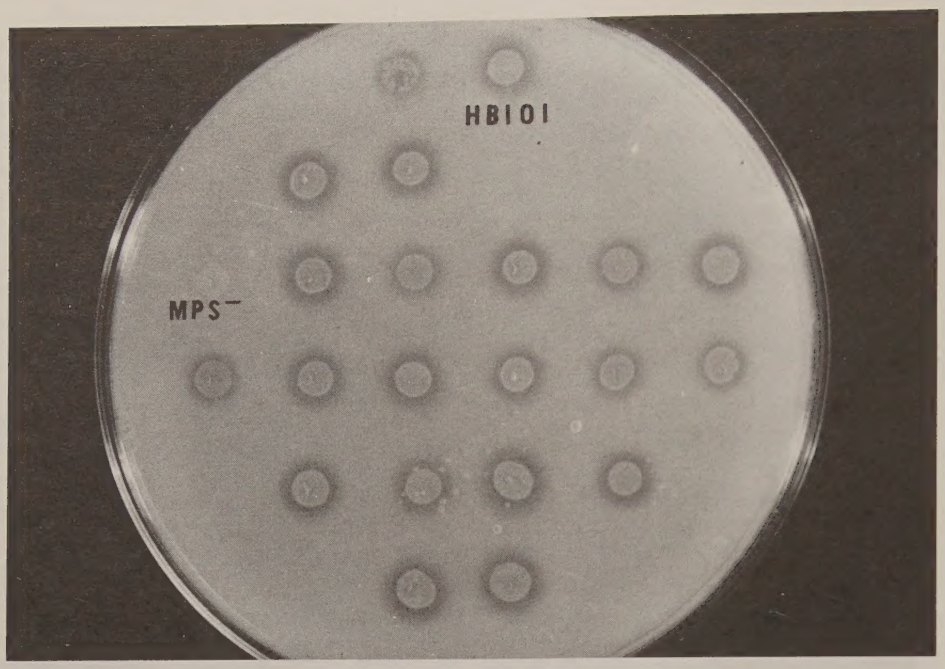

Figure 2. A MPS⁻ mutant of *E. coli* strain HB101 generated via transposon (Tn5) mutagenesis. With the exception of the parent strain, all bacteria spotted on this DCP4A+ (DCP4+ media includes 20 μg/ml of amino acids necessary for HB101 growth), plate are Tn5 insertion mutants. The colony labelled MPS⁻ is no longer capable of solubilizing exogenous mineral phosphate and grows somewhat more slowly than the other colonies. Other phenotypes such as supersolubilizers (i.e., not repressed by 20 mM exogenous Pi) and those incapable of growth without additional exogenous Pi have also been isolated. Frequency of occurrennce of MPS mutants, both with transposon and chemical mutagenesis methods, are in the range expected for "single hit" mutations.

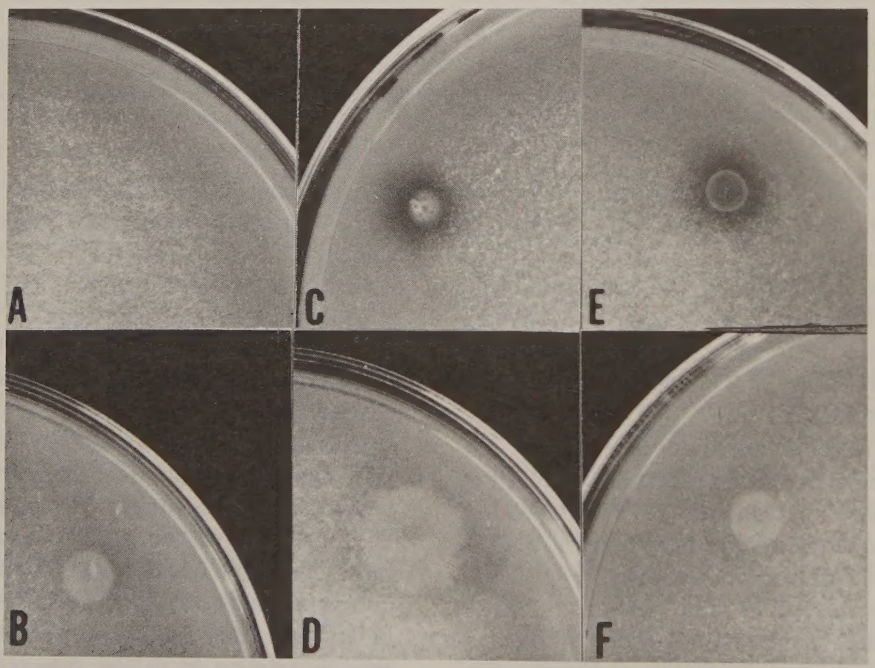

Figure 3. Molecular cloning of a MPS gene from *E. herbicola* into *E. coli* strain HB301. A. HB101 shows no visible growth on HAP4A+ media[1]. Hydroxyapatite (HAP) provides the only source of P in this media (Pi concentration ~ 1 μm). B. Normal colony growth is shown on HAP4A+ media supplemented with 20 mM Pi. C. *E. herbicola* shows both growth and HAP solubilization on HAP4A+ media. D. *E. herbicola* shows vigorous growth but repression of the MPS trait when grown on HAP4A+ media supplemented with 20 mM Pi. E. Recombinant HB101 (designated MPS1) shows the *E. herbicola* MPS phenotype, i.e. growth and HAP solubilization on HAP4A+ media. F. The recombinant exhibits the characteristic repression of the MPS trait in the presence of 20 mM exogenous Pi.

[1]HAP4A+ media consists of the same minimal components as DCP4A+ media except that the *in situ* precipitation of DCP is replaced by addition of powdered, sterilized HAP. Before addition, the HAP was washed and centrifuged repeatedly with sterile double distilled water to remove Pi. The Pi concentration of HAP4A+ media was in the range of 1 μM. Additional exogenous Pi was added as potassium phosphate. The pH was adjusted to 7.2 with 1N sodium hydroxide.

system. Overexpression of a Pi transp system would allow the bacteria to ta up exogenous Pi with a much grea efficiency than the parent strain. Th in turn, might remove the internal starvation condition necessary for duction of the MPS trait. It has be shown previously that the *pst* system *E. coli* is part of the Pho regulon (viewed in Torriani and Ludtke, 1985

Another type of experiment, shown Figure 3, takes advantage of the diff ential MPS capability of two bacter genera. HB101 can solubilize dicalciu phosphate in agar within 48 hours b is incapable of solubilizing hydroxyap tite (HAP). Therefore, HB101 cann grow on minimal media where HA provides the only source of P. *E. h bicola* can solubilize both of these for of mineral P. Using this difference phenotype, we have cloned a piece of *herbicola* DNA into HB101 that confe the HAP solubilizing and growth c pacity to HB101. Importantly, additi of 20 mM Pi to the media inhibits HA solubilization in the recombinant. Th is the same level of Pi necessary to tota inhibit the MPS trait in wild type *herbicola* (Figure 1). These types of da have led us to propose that at least so bacteria regulate their mineral P so bilization in response to Pi starvation a manner similar to the previously d cussed organic P scavenging system. W have tentatively proposed to name t gene(s) involved in mineral P scaveng *mps* for mineral phosphate solubili tion.

While the identification and man ulation of phosphate solubilization ge could have a significant impact on mo ern agriculture, many years of basic search will be required to understand t behavior and potential utility of t complex system. Ideally, biological s tems such as MPS bacteria will be us in conjunction with a number of oth techniques currently in use or develo ments that enhance the P-use efficien of crops and minimize P-retention in soil. These techniques include the use partially acidulated phosphate ro (PAPR), a fertilizer formulation cently developed by the Internatio Fertilizer Development Center (IFD at Muscle Shoals, Ala., that has a co siderably longer residual availabil than such fully-acidulated P-fertiliz

as single- or triple-superphosphate.

In the short term, P-use efficiency can be greatly enhanced through cultural practices, including banding or side-dressing as opposed to broadcasting; the latter is inefficient and can quickly lead to P retention. Also, organic matter such as crop residues and animal manures as well as certain crop rotation practices, probably would enhance the availability and efficiency of P-fertilizers.

In addition to the approaches discussed above, it is important to recognize that a number of physical and biological parameters other than phosphate solubilization *per se* can play important roles in P-use efficiency in the field. The morphology of the plant root system, including the amount of root hair development will influence greatly the plant's ability to "mine" the soil for a number of crop plants (Tinker, 1980). These areas are the subject of a great deal of research and have been reviewed elsewhere (Fried and Broeshart, 1967; Rovira and Davey, 1974; Tinker, 1980).

The successful use of either mineral or organic P solubilizing bacteria in agriculture will be based on an understanding of the metabolic bases for these traits. Work on the PSI component of the *Pho* regulon has provided a model for these types of studies. Current approaches to understanding nitrogen fixation have also focused on molecular genetic analyses. A mechanistic understanding of these traits may allow selection or development of strains of mineral or organic P solubilizing rhizobacteria specifically adapted to live on or near the roots of major crop plants. Recently, promising results have been obtained by the use of molecular biological approaches to identify recognition factors by rhizobacteria (Long et al., 1982). These types of studies have demonstrated the utility of recombinant DNA methods as tools to aid understanding of how biological systems work. With this understanding, it may be possible to develop assays for selecting naturally occurring soil bacteria as P biofertilizer agents. Alternatively, these agents may be developed via the methods of biotechnology. It is far too early, given the present state of our knowledge, to predict the most useful approach.

Successful isolation and/or development of bacteria that preferentially colonize specific plants could create potential vehicles for this component of a biological phosphate fertilizer system. Enhanced solubilization of mineral and organic P would be used to raise the effective concentration of soluble Pi in the soil solution. The Pi would still have to reach the absorbing surface of the plant (or mycorrhizal hyphae) and be taken up. However, solubilization provides an essential first step in this process. Therefore, a major challenge for the near future lies in the identification and characterization of the *mps* genes. Success in this area, when used in conjunction with known organic P solubilizing genes, may provide a key component of a biorational approach to sustainable and ecological P fertilization in agriculture.

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Reduced-input agricultural systems: Rationale and prospects

Frederick H. Buttel, Gilbert W. Gillespie, Jr., Rhonda Janke, Brian Caldwell, and Marianne Sarrantonio

Abstract. *In many respects the long standing and vigorous debates over alternative agriculture and organic farming are becoming less strident and less polarized. However, despite the mounting evidence that key elements of both the conventional and alternative agricultural communities are beginning to "build bridges" to each other, and to establish formal institutional programs and arrangements for improved communication and program development, important differences continue to separate the proponents and opponents of alternative agriculture. In part, these lingering differences result from the lack of adequate and reliable data, misinformation, and faulty data analyses. In order to clarify those issues which continue to divide the critics and advocates of alternative agriculture, this reappraisal of the debate begins with a methodological critique of comparison studies of conventional and organic farms. Also included is an assessment of fertilizer and pesticide use in American agriculture, the environmental impacts of conventional and reduced-input systems, the relationship between alternative agriculture and efforts to save the family farmer, and the prospects for increased public sector research on reduced-input farming systems.*

Introduction

It is now well over a decade since the onset of vigorous debates over alternative agriculture and organic farming. In certain respects the debate has become less polarized. It is not uncommon now, for example, to see research projects and courses relating to alternative agriculture at land-grant universities (Youngberg and Buttel, 1984a, 1984b). Nevertheless, substantial differences still separate proponents and opponents of alternative agriculture. In this paper we consider several key issues that have not been resolved, such as the environmental effects of different production methods, how essential chemicals are in the U.S. agricultural system, and the appropriateness of different research methods. Beyond these disagreements concerning the comparative merits of alternative and conventional systems, there are areas in which the reasoning behind the support of alternative systems by their proponents is inadequately developed or even misdirected. Examples discussed here include the comparative importance of off-site environmental damage and loss of soil productivity, and the relation of alternative agriculture to family farming. Finally, we discuss the rationale for greater federal support of research on alternative agriculture and the prospects that such support will be forthcoming.

Reduced-input agricultural systems

Although the terms "alternative agriculture," "organic farming," and "regenerative agriculture" have all come to be used in a roughly synonymous way, we prefer the term "reduced-input agricultural systems." These are systems in which direct or indirect use of purchased petrochemical-based inputs is significantly decreased in comparison with more "conventional" production systems. This definition is intended to move the debate on alternative agriculture away from arguments about "organic" versus "conventional agriculture, in keeping with the evolution of the alternative agriculture movement in the past decade to encompass systems whose use of chemical fertilizers and pesticides is modest but significantly reduced by comparison with conventional systems (USDA, 1980; Youngberg, 1984). The term is also intended as a reminder that an effective production system must respond to farmers' dissatisfaction with the large cash outlays that are required for inputs in prevailing practices, a dissatisfaction that has become more pronounced during the current era of farm financial stress and crisis. This consideration should be obvious but it has not always been given the attention it deserves in alternative agriculture circles (Dalescki and Beale 1984).

It has only been a few years since the alternative agriculture movement began to stress that reduced-input agricultural systems should be conceived as a set of management practices and technologies that farmers can use to overcome problems not solved by "conventional" practices. It is unlikely that the majority of present farmers will consider adopting reduced-input practices to help American agriculture become more "sustainable" or, unprompted by government regulation, to reduce the substantial environmental externalities of American agriculture. U.S. farmers are, in the aggregate, among the most anti-environmental of major social groups (Buttel et al., 1981; Buttel and Murdock, 1986) and the evidence from studies of organic farmers is that these farmers generally have not adopted nonchemical practices for philosophical, religious, or ideological reasons (Lockeretz and Wernick 1980; Harris et al., 1980). Instead, these practices have generally been employed to solve a particular production or an

Frederick H. Buttel is Associate Professor, Department of Rural Sociology; Gilbert W. Gillespie, Jr., Rhonda Janke, Brian Caldwell, and Marianne Sarrantonio are graduate students, Department of Sociology, Department of Agronomy, Department of Floriculture and Ornamental Horticulture, and Department of Agronomy, respectively, Cornell University.

mal or human health problem.

Whatever term one uses, one must not overlook the fact that reduced-input systems are not all alike, since even in one country like the United States there is a great diversity of agroecological zones, commodities, and farm production problems. The alternative agriculture movement has thus far given primary attention to reduced-input systems relevant to the Corn Belt and the upper midwestern and northeast dairy zones (typically involving legume-based crop rotations). However, we need to develop reduced-input systems that can address the qualitatively different--and often much more difficult--production and ecological problems of such production systems as those involving wheat in the Palouse, fruit in the Northeast, or soybeans in the South (USDA, 1980, p. 6-9).

The debate over alternative or reduced input agriculture

Arguments made by both advocates and critics of alternative agriculture have several limitations and shortcomings. This paper, which is intended to be a fresh reappraisal of the debate, will make five major points. *First,* both in micro (farm-level) and macro (simulated national-level) comparisons of the two types of farming, there has been misuse and faulty interpretation of data on both sides. In particular, critics of alternative agriculture fail to recognize the "integration efficiences" of these cropping systems. *Second,* both sides have a tendency to exaggerate the extent to which U.S. farmers depend on pesticides and synthetically compounded or other "artificial" soil amendments. *Third,* defenders of conventional agriculture severely underestimate the environmental costs of conventional practices, especially the almost-inevitable soil erosion and run-off problems that will lead to devastating destruction of off-site water (and water-related) resources over the next 30 to 40 years. Alternative agriculture proponents argue that conventional practices threaten agricultural "sustainability," the term sometimes being involved in a manner that is almost metaphysical. However, they fail to appreciate that the principal long-term environmental and resource implications of conventional agricultural practices in the United States are probably those of the off-site rather than the on-site environment.

Fourth, arguments in favor of alternative agriculture often confound advocacy of technology (i.e., "organic" vs. "conventional" practices) with advocacy of a particular agricultural structure, namely, "small family" farms vs. "large, industrial, factory" farms. While reduced-input practices tend to be associated with smaller farms, for which they may be especially well-suited, large organic farms do exist. Moreover, as is discussed later, reduced-input agricultural technology is not likely to lead to the renaissance of small or family farms.

Finally, given that overcapacity, overproduction, and soil erosion problems are likely to be the most important policy problems in American agriculture for the foreseeable future, a case can be made on both micro and macro grounds for stressing public research into improving productivity by minimizing inputs rather than merely by increasing output. Also, petrochemical input prices may well rise when the world recession-induced oil and natural gas gluts have ended, further increasing the attractiveness to farmers of better-developed reduced-input systems. We develop these arguments on behalf of reduced-input systems as one possible alternative appropriate for some producers. At the same time, we recognize that not all producers will necessarily be able to reduce petrochemical inputs for all commodities significantly while remaining competitive in world markets.

Comparisons of organic and conventional agriculture: A methodological critique

Proponents of alternative or reduced-input agricultural systems have typically used farm-level comparisons of these two systems as a major research tool (e.g., Berardi, 1978; Harwood, 1984, 1985; Klepper et al., 1977; Lockeretz et al., 1984; Oelhaf, 1978; Pimentel et al., 1983, 1984; Shearer et al., 1981; USDA, 1980). Critics of reduced-input (especially organic) systems also use comparisons (CAST, 1980; Knutson, 1984; Olsen et al., 1982), often supplemented by simulations of the aggregate impacts of "widespread adoption of organic farming practices" (especially Olsen et al., 1982). But as will be stressed later, critics of alternative agriculture have not used actual farm data in their research. Aldrich (1980), the most visible critic of alternative agriculture and chair of the controversial CAST (1980) task force report on organic farming, has been strident in arguing that data collected from working farms are without scientific utility because researchers cannot adequately manipulate treatment variables or hold other variables constant (see Lockeretz, 1985, for a different view).

These opposing bodies of literature can be roughly summarized as follows. On the one hand, studies conducted or frequently cited by alternative agriculture proponents show that eliminating or greatly reducing the use of petrochemicals results in modest decreases in yields (typically 5-15%, depending upon the commodity) and increased labor requirements, but also in reduced variable costs, comparable or even higher profit, substantially increased "energy efficiency," and substantially less soil erosion and run-off (see especially Lockeretz et al., 1981). On the other hand, comparison studies done or frequently cited by opponents show startling shortcomings of organic farming, namely lower yields, aggregate production levels, and export levels, and phenomenal product price increases (-30, -54, -62, and 380%, respectively, according to Olsen et al., 1982).

The source of these diametrically opposed results lies in a combination of methodological problems and faulty inferences--created perhaps because the authors of these studies have collected their data and written their results in the midst of a politically sensitive debate. There are also major differences in data collection between supportive and negative studies. Studies supportive of reduced-input agricultural systems have largely been based on farm-level data collected from working or experimental farms of both types. Researchers have generally sought at least to describe, and perhaps also to evaluate, the differences between alternative and conventional farmers and farming practices. Studies of this sort have several advantages

(Lockeretz, 1985). In particular, micro-level studies of a descriptive or evaluative nature have already largely accomplished what they can accomplish at this level of analysis: to demonstrate the feasibility of significant reduction in input usage consistent with minimizing per unit production costs, and identifying those commodities, such as potatoes and apples, for which reduced-input practices currently have little potential.

Studies critical of reduced-input agricultural systems, by contrast, have never, to our knowledge, been based on on-farm data from matched sets of conventional and organic farms. Instead, the most typical procedure has been to utilize experimentally-derived data in which one set of production practices--use or nonuse of synthetically compounded fertilizers and pesticides--is varied between the "conventional" and "organic" farming trials. These micro data are then used in a macro simulation model in which impacts are projected for a mass conversion of American agriculture toward "organic farming."

The comparison studies favorable to reduced-input agriculture that have been described above, in addition to being able to answer only a limited range of questions (Lockeretz, 1985), have another key limitation: they generally fail to recognize that macro-level consequences cannot be accurately inferred from micro-level data. For example, many contemporary organic farmers get substantial amounts of nutrients from off-farm sources of organic wastes at nominal prices. Were reduced-input agriculture to increase in prevalence in particular regions, demand for these organic wastes would increase, suppliers would be able to charge a market price, and the profitability of reduced-input systems would be significantly modified. We still need macro-level studies of the impacts of reduced-input systems, based on reasonable assumptions (e.g., *x* percent "conversion" among *y* type farms for *z* commodity at some particular time, rather than the wholly unrealistic assumption that there will be a "widespread conversion to organic farming practices", as was assumed by Olsen et al. (1982), for example.

The limitations of comparison studies of conventional and organic agriculture conducted by opponents have different but more severe problems. First, the comparison data used as an input to macro simulation models are profoundly unrealistic. Reduced-input producers in practice do not merely terminate pesticide and fertilizer use; instead, they replace petrochemical inputs with a variety of practices, such as crop rotations; legumes, cover crops, and green manures; and addition of livestock enterprises. Moreover, they derive "integration efficiencies" from these substitutions (Harwood, 1985). Second, assessing reduced-input agriculture on the basis of national simulations such as those of Olsen et al. (1982) Knutson (1984), and Aldrich (1980) are equally unrealistic for reasons discussed above.

We believe that widespread conversion to organic farming practices with current technologies is grossly unrealistic and has not been advocated as a meaningful short- to medium-term goal by responsible persons in the alternative agriculture movement. A macro-level analysis of such a conversion, even if it were based on on-farm data representative of the practices that reduced-input producers use to compensate for the lack of petrochemical inputs, is pointless for agricultural or research policy.

Are all U.S. farmers dependent on pesticides and fertilizers?

Proponents of both conventional and organic farming seem to assume that virtually all farmers use high levels of pesticides and fertilizers. To the former, this shows that these off-farm inputs are essential for a productive, efficient U.S. agriculture. To the latter, on the other hand, widespread chemical use means that continued high agrochemical consumption will cause American agriculture to become "unsustainable" (about which more later). Both views understate the extent to which U.S. farmers do not use chemical fertilizers and pesticides. For example, no herbicides, insecticides or other pesticides are applied to about 52% of U.S. wheat, 42% of sorghum, and 59% of combined oats, rye,and barley. Thus, significantly more U.S. farmers than those self-identified as "organic" farmers or "alternative agriculturalists" manage to get along without relying heavily on agrochemicals.

Further evidence in support of thi notion comes from a statewide random sample survey of 386 New York Stat farmers conducted in 1979 (unpublishe data); 7.3% of sample farmers used ne ther pesticides nor purchased chemica fertilizers. Also, an additional 9.9% in dicated that they use no chemical fe tilizers, while 5.2% more reported tha they used no insecticides, herbicides, o fungicides. No doubt many additiona farmers who use either fertilizers or pes ticides do so on only a few fields o crops. When we related four economi measures of farm household well-bein (net farm income, total family income net worth, and debt) to several farm characteristics, including the use of ag ricultural chemicals, we found tha whether the farm used synthetic fertil izers alone, synthetic pesticides alone both, or neither had little or no net im pact on household well-being.

Both the national and New York Stat data, while by no means conclusive, sug gest that there are many more instance of successful reduced-input agricultur than either opponents or defenders o alternative agriculture typically ac knowledge. These systems should be be ter understood by researchers from bot sides. There is need for both agronomi and agroecological analyses of thes farming systems as well as socioeco nomic knowledge on the reasons fo adopting, and the effectiveness of, thei reduced-input practices. Also, "alter native agriculture" researchers shoul expand their research to include farmer who have substantially reduced, but no eliminated, their reliance on agricultura chemicals.

The environmental impacts of conventional and reduced-input agricultural systems: Between "ostrichism" and metaphysics

More than two decades into a ne milieu of agricultural politics that wa initiated by Rachel Carson with *Silen Spring* in 1962, proponents and critic of reduced-input agricultural system appear to be divided more fundamen tally on environmental consideration than on any other issue. The most ou

spoken critics of alternative agriculture appear to be radically anti-environmental, even by comparison with the rank-and-file of "conventional" agricultural scientists. On the other side, the alternative agriculture movement's ideology and values mostly revolve directly or indirectly around environmental considerations (Youngberg, 1984).

There is room for argument with both sides. Some critics of alternative agriculture (especially CAST, 1980) exhibit "environmental ostrichism." They cannot find any environmental reasons for concern about prevailing agricultural practices. In the most extreme forms (e.g., Aldrich, 1980), this posture is buttressed by highly biased data showing the environmental superiority of current practices over a hypothetical organic farming system that has had to expand over every spare acre because of the assumed gross inefficiencies of organic agriculture.

Among the environmental problems of U.S. agriculture, two should be stressed that either affect us now or will in the future. These are massive destruction of off-site water and water-related resources because of accelerated erosion and run-off, and the mining of underground aquifers. Crosson and Brubaker (1982, p.151), in their extensive study of the future environmental impacts of U.S. agriculture, have concluded that "erosion, in our judgment, is easily the major threat to the nation's environment posed by the projected levels of crop production and land use (to the year 2010)." They project that U.S. agriculture, which already causes about $2.2 billion in annual damages to off-site water and water-related resources, such as losses due to increased flooding (Clark et al., 1985, Chapter 5), will account for a near doubling in sediment delivered to water bodies from 1977 to 2010. The projected increase is from 748.3 million to 1,449.8 million tons annually, even taking into account expected adoption of reduced tillage soil conservation practices by U.S. farmers. The off-site impacts are expected to be at least proportional to the increased quantity of sediment.

Another almost certain development is the curtailment of the use of subsurface aquifer water for irrigation in the southern Great Plains, whether for political or ecological reasons (Frederick, 1980). This water is largely used for irrigated corn and sorghum for the region's large cattle industry. As it becomes less available, some grain and cattle production will shift to other regions (Raup, 1980).

There are other less certain but plausible environmentally-related impacts of current agricultural practices. These include serious pesticide and nutrient contamination of surface and subsurface waters, resulting in major health problems or abatement expenses, and dislocations caused by sharp energy price increases or supply shortfalls as a result of energy supply interruptions. These environmental considerations must not be ignored when formulating agricultural research priorities.

Alternative agriculture proponents have been more sensitive to the environmental implications of current agricultural practices. Nevertheless, some of the ecological arguments on behalf of alternative systems have been misdirected. For example, certain reduced-input practices are far more effective in controlling soil erosion than row-crop monocultures on steeply sloped lands. But from a national perspective, the main benefit from controlling the erosion is not primarily to sustain our productive capacity, an argument often made in support of reduce-input systems. The proportion of U.S. farmland vulnerable to irreversible productivity declines because of erosion is small; 70% of "excess erosion" (above the five ton per acre benchmark beyond which erosion is thought to be a serious problem) occurs on only 8.6% of farmland, most of which is steeply sloped and marginal to U.S. productive capacity (Batie, 1983). Some soils, because of their depth of topsoil, are experiencing erosion losses of 25 or more tons per acre annually and can continue to do so indefinitely with no productivity loss (Larson et al., 1984). However, erosion endangers the quality and quantity of water resources at least as much if not more than it does the productivity of farmland. Therefore most farmers, except some in regions where steeply sloped lands predominate, may never need to adopt reduced-input practices to any large extent to preserve the long-term productivity of their soils. Indeed, reduced-input practices may only become relevant if farmers are forced, through regulation, to reduce the surface and subsurface transport of soil, chemicals, and salts that adversely affect off-site resources.

The most common rationale advanced by alternative agriculture proponents for restructuring American agriculture is that conventional practices are "unsustainable." "Sustainability" often takes on metaphysical overtones (but see Edens, 1985, and Douglass, 1985, for some of the better formulations of the "sustainability" notion). Underlying most sustainability arguments for alternative agriculture is the notion that U.S. agriculture uses high levels of nonrenewable inputs--land, irrigation water and oil--and that when these inputs are depleted the system will stumble, if not collapse.

Indeed, many agricultural systems in the world, especially those of smallholder peasantries in Third World regions, do face major constraints of a sustainability nature. U.S. (and, in general, western) agriculture, however, is plagued by chronic overcapacity. Overcapacity is currently creating intractable economic problems for farmers, and political problems for governments, but it provides a comfortable food security situation for the foreseeable future. This is not to ignore the land destruction that is widely recognized to occur in U.S. agriculture. But the most likely long-term environmental consequence of conventional agriculture in the United States is not dependence on certain nonrenewable inputs that might become scarce and costly. Instead, if farmers are compelled to greatly reduce erosion and run-off of chemicals and sediments to protect water resources, this would be a powerful inducement for them to make far-reaching changes in their production practices, often in the direction of reduced-input systems. These changes will be acclerated if N fertilizer becomes expensive or its supply unreliable (but given the vulnerability of U.S. agriculture to shifts in the price, and especially interruptions in the supply of fertilizer inputs, the federal government might step in to stabilize fertilizer supplies and prices).

Clearly, the U.S. agricultural system should be based more completely on sustained use of renewable resources. But the most compelling argument for research on reduced-input agricultural systems may be that it can give farmers more options. Many farmers with shortages of investment capital will be interested in ways to greatly reduce their variable costs without diminishing net returns. Many more farmers will find these sytems attractive if they are forced to stop imposing high costs on the rest of the society through destruction of water and water-related resources. Still other farmers may worry about shortages or high prices for fertilizers and other chemicals and will want to reduce their dependence before problems emerge. These benefits do not involve sustainability in the sense of averting ecologically-induced system collapse.

Can alternative agriculture save the family farm?

Jackson and Bender (1984 p. 34) have written of "a unifying concept for agriculture which features information over energy, small scale over large;" they continue: "Such an agriculture would be run by naturalists, not industrialists" (1984 p. 36). This elegant language conveys a widely accepted premise among many "alternative agriculturalists"--that this type of agriculture is connected to restoration of family or nonindustrial farms. This effect would be indirect if a factor like high energy prices makes the large, "industrial" farm obsolete, instead favoring smaller farms with more environmentally-sound practices. The effect would be direct if alternative technologies are developed that are both economically superior to conventional practices and principally suitable for small operations. One kind of evidence typically employed to support these arguments is that farm operators who use organic or reduced-input practices tend to operate smaller farms than do "conventional" farmers (see, for example USDA, 1980). Second, the adoption of conventional, input-intensive agricultural practices since World War II was associated with trends toward fewer and larger farms, the rise of large-scale, industrial agriculture, and the shrinking position of the medium-sized family farm (see, for example, Buttel, 1984; Dovring and Yanagida, 1979; LeVeen, 1978).

We consider it quite unlikely that there will be a renaissance of the small family farm associated with the development of significantly more effective reduced-input practices, for the following reasons (Buttel and Gertler, 1982; Youngberg and Buttel, 1984a):

1. Public policy, especially tax, credit, and commodity policy, has probably been at least as important as technology in shaping structural change in U.S. agriculture; accordingly, if these patterns of structural change are to be attenuated or reversed, public policy changes will be far more effective than changes in research and technology.
2. It is not clear that either large-scale or small-scale units have any inherent agronomic advantages or liabilities with respect to efficient resource management.
3. Large-scale units in the United States enjoy significant scale economies, attributable largely to efficient use of machinery, that probably continue to even larger scales ($500,000 or more annual gross sales for most commodities) than previously thought (OTA, 1985).
4. Large-scale farms would enjoy major advantages, such as superior access to credit, in adjusting to shocks such as higher energy prices.
5. Some large-scale "organic" farms do exist, apparently without any diseconomies of scale relative to smaller organic farms (Lockeretz, et al., 1981; USDA, 1980).

Nonetheless, reduced-input practices are particularly suitable for smaller operations in that the risks of conversion are smaller than for larger operators; smaller operators are more likely to have low debt and significant off-farm income, thereby making the transition period easier. Also, many smaller operators have available the additional labor typically needed for reduced-input practices; this additional labor input often yields significant additional benefits if combined with sales in "organic" specialty markets--an outlet that would, of course, disappear if organic practices are more widely adopted.

Conclusion: The rationale and prospects for public research on reduced-input agricultural practices

This discussion leads to three inte related justifications for expanded publ research efforts on reduced-input agr cultural systems. *First,* it is almost ce tain that chronic overcapacity wi present a crucial policy problem for U. agriculture for the foreseeable futur Reduced-input practices, if they min mize production costs per unit and r duce levels of supply, would help solv this problem. Reduced-input agricu tural systems improve productivity b reducing use of input, rather than b increasing output. This argument quite different from those typically mad by alternative agriculture proponent we are suggesting that a key argumer for reduced-input practices is overca pacity, more so than the current or fu ture scarcity of inputs.

Second, there are several environmer tally-related rationales for further effor to develop reduced-input systems; i particular, reducing the off-site costs conventional agricultural productio practices deserves more weight here tha is typical in both alternative and co ventional agricultural circles. *Third,* research thrust toward developing r duced-input agricultural systems shoul be pursued because farmers are begi ning to ask for this type of research; th land-grant system, given its largely pub lic (especially state government) fund ing, has an obligation to expand th range of choices available to farmer This argument is further buttressed b the existence of farmers who, in a broa sense, are already using reduced-inpu practices, for example, some of those i the New York State survey mentione earlier.

We also want to caution that reduce input systems should, over the short- t medium-term, be regarded as one po sible alternative for some producer Thus, in the short-term there is no nee to devote a large proportion of the lan grant university effort to this topic. W know too litle about the resource an economic constraints that will face U. agriculture two to four decades into th future to say that only one research ap proach should be emphasized. This ap

plies as well to conventional chemical-intensive systems, basic research on photosynthetic efficiency, use of molecular and cell biology techniques to manipulate single-gene traits, or reduced-input agricultural systems, no one of which should dominate the land-grant university research agenda. Reduced-input agricultural systems should be among these approaches, given their already substantial constituency and their ability to alleviate some of the long-term environmental constraints that many--including mainstream observers (e.g., Crosson and Brubaker, 1982)--now see as likely.

Our arguments regarding public research are weakest on macro grounds since there has been no competent, comprehensive research on the macro implications of reduced-input practices using reasonable assumptions. Still, we can make some guesses regarding the macro implications of using reduced input practices on two-fifths of U.S. cropland by 2010, for example. By 2010, say, all other things being equal, aggregate output would decrease, perhaps by about 5 percent. This would likely increase net farm income, reduce surpluses and export revenues, and raise land prices relative to a baseline, "conventional" projection. In a highly competitive world agricultural economy, public intervention to limit land price increases might be necessary to control production costs and to avoid jeopardizing export sales. But these are just guesses and are not a substitute for careful research.

Finally, if the reduced-input approach is pursued more vigorously in the future, it should not be largely confined to applied research. Realizing the full potential of "integrative efficiencies" (Harwood, 1985) will require the development of a basic science knowledge base in agroecosystems (Jackson and Bender, 1984; Lowrance, et al., 1984). Effective nonchemical ways to supply nutrients and protect plants will have to be based on far more sophisticated knowledge than currently exists on ways that agroecosystem processes can be mimicked to achieve agronomic goals.

A related rationale for a significant public research role in developing reduced-input systems as one of several approaches to solving long-term agronomic, environmental, and economic problems of the farm sector is that these technologies are unlikely to be developed by private sector firms. In particular, these firms will not be interested in developing the basic or fundamental agroecosystems knowledge base (as they have begun to do in, for example, plant molecular biology). The principal interest of agricultural input firms will be in selling inputs--not in reducing their usage--so that the public research sector role will be crucial in developing a diversity of agronomic approaches that contribute to the long-term flexibility of U.S. agriculture in the face of changing conditions. The efforts of the Rodale Research Center and the Land Institute will continue to be useful and important, but a larger public sector role in developing reduced-input systems will be necessary in both performing basic research and adapting reduced-input systems to the diversity of agroecological conditions.

What are the prospects for basic and applied public research on reduced-input agricultural systems, whether in the land-grant system or the Agricultural Research Service?

The land-grant system is undergoing some major shifts in funding base and clienteles. These shifts include a pressure to greatly expand basic research in molecular and cell biology and to deemphasize highly applied, routine, commodity-oriented research (Buttel, et al., 1986; Buttel and Youngberg, 1985). They are occurring in a milieu of a government fiscal crisis and Gramm-Rudman deficit reduction legislation that has ominous implications for levels of public funding. Private industry's share of funding of land-grant research is increasing, and perhaps with it industry influence over research priorities, though industrial funding still generally remains less than 10 percent of the total in most experiment stations.

Current trends have mixed implications for an expanded emphasis on reduced-input agricultural systems. On the one hand, it is now difficult for experiment stations to add any new activities, especially applied activities that have little ability to generate extramural funding. With recent shifts toward basic subcellular research and away from applied research, traditional commodity producer groups are beginning to realize their losses and and are reasserting their prerogatives to state legislatures and land-grant university officials. This makes it more difficult for new clienteles to capture a share of the pie.

On the other hand, the new climate for basic research may be propitious for an increased emphasis on basic agroecosystems research, which is probably the most important long-term priority for reduced-input agricultural systems at this point. (Experiment stations, however, generally see basic research as equivalent to molecular and cell biology, an assumption that must be directly confronted by agroecologists.) Also, new biotechnology techniques promise to provide a broader range of tools for agroecosystems design. For example, single-gene traits such as allelopathic mechanisms may have long-term potential for controlling weeds without chemicals, and gene transfer techniques may be applicable to breeding new crop varieties consistent with agroecological processes. Third, the commodity-oriented clientele system for land-grant research has historically contributed to biases toward highly specialized monocultural producers. The reduced influence of commodity groups on experiment station research might therefore create "space" for a reduced-input approach, which almost inherently is multi-commodity in nature.

This appraisal, while only partial and tentative, suggests that proponents of reduced-input approaches will have to struggle to obtain the public research programs that they want, but also that they can be successful. A key lesson of the recent massive increase in basic subcellular biology programs in the land-grant universities is that shifting research priorities is far easier if prominent experiment station officials, in statesman-like fashion, push for a new thrust in the long-term interest of the agricultural industry. Reduced-input agricultural systems should qualify for this type of statesmanship, and we hope that it can emerge in the near future.

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IFOAM conference events announced

Advance registration is underway for the Sixth International Scientific Conference of the International Federation of Organic Agriculture Movements Aug. 18-21 at the University of California at Santa Cruz. It is one of four August events organized by IFOAM and the university's Agroecology Program.

The first is an Aug. 11-17 agricultural tour by chartered bus through northern and central California. It features visits to farms, including specialty crop operations using organic methods, that are working to incorporate sustainable agriculture techniques. The itinerary also includes a stop at agricultural facilities at the University of California at Davis.

Following the scientific conference, IFOAM's General Assembly has scheduled an Aug. 22-23 session for members only. The final event is an Aug. 25-30 short course in agroecology organized jointly by the Division of Biological Control at UC Berkeley and the Agroecology Program at UC Santa Cruz.

The 4-day scientific conference will focus on research and issues related to agroecology and the development of sustainable agricultural systems. It continues the series started in 1977 in Switzerland and continued in 1978 in Canada, 1980 in Belguim, 1982 in the United States, and 1984 in Germany.

Special package rates for on-campus housing and meals are available for conference participants. The registration fee also is $25 less if paid by July 15.

Conference and farm tour information is available by writing IFOAM Conference, Agroecology Program, University of California, Santa Cruz, CA 95064. Short course information is available by writing Miguel Altieri, Division of Biological Control, University of California at Berkeley, 1050 San Pablo Ave., Albany, CA 94076 or calling 415-642-9802.

The potential for regenerative agriculture in the developing world

Charles A. Francis, Richard R. Harwood, and James F. Parr

Abstract. *Increased food production and greater income for farm families are primary goals of agricultural development in the Third World. Most strategies to achieve these goals are unrealistic in assuming that limited resource farmers can move out of basic food production in multiple cropping systems to high-technology monocropping for export. These strategies are based on petroleum-based inputs that demand scarce foreign exchange. They may include excessive use of chemical fertilizers and pesticides, which adds unnecessary production costs, endangers the farm family, and degrades the rural environment. Dependence on export crops and world markets is economically tenuous, especially for the small farmer. Future agricultural production systems can be designed to take better advantage of production resources found on the farm. Enhanced nitrogen fixation, greater total organic matter production, integrated pest management, genetic tolerance to pests and to stress conditions, and higher levels of biological activity all contribute to resource use efficiency. Appropriate information and management skills substituted for expensive inputs can further improve resource use efficiency. On the whole farm level, appropriate cropping on each field can be integrated with animal enterprises, leading to a highly structured and efficient system. Such systems can serve the needs of national agricultural sector planners, who in many countries are concerned with increased self-reliance in farming inputs and in production of basic food commodities. This includes a realistic focus on training of local development specialists, increased research on food crops under limited resource conditions, and providing information, incentives, and appropriate technologies for operators of both large and small farms. Well-conceived national plans include varied food production strategies and options for farmers with different resource levels.*

Introduction

Strategies to increase food production in the developing world need to include options consistent with the different land and capital resource levels of farmers in each region. Concern for improving the long-term productive capacity of soils, the sustainability of crop and animal production, and the quality of life in the rural environment has generated increased interest in alternative approaches to agricultural development, especially because of the current food crisis in Africa (Francis and Harwood, 1985; Timberlake, 1985).

Charles A. Francis is Professor of Agronomy and Extension Crops Specialist, University of Nebraska, Lincoln, NE 68583. Richard R. Harwood is Program Officer and Agronomist, Winrock International Institute for Agricultural Development, Morrilton, AR 72110. James F. Parr is National Program Leader, Dryland Agriculture and Soil Fertility, ARS-USDA, and Coordinator, Dryland Agriculture Project, ARS-USDA/USAID, Beltsville, MD 20705.

Many development activities are based on high-technology solutions and on transfer of concepts and technologies from one country or region to another (Harwood, 1979; 1983). These agricultural methods may be difficult to adapt to conditions in a specific country, since they are based on chemical fertilizers and pesticides often not available in a country, or acquired only at a high cost. For example, Maher (1982) and Gonsalves (1982) discuss the complications of using these inputs in Tanzania. As a result, fossil fuel-based technologies have not reached most limited resource farmers of the world (Francis and Harwood, 1985). A growing awareness of the global reality of a declining amount of arable land (Urban and Vollrath, 1984) and finite fossil energy reserves (Brown, 1986) leads to a sobering assessment of how to approach agricultural development. The unique problems of farmers in chronically resource-poor regions, who are faced with limited capital and relatively low production potential (Timberlake, 1985), present a great challenge. They need a range of new solutions; several alternatives were summarized by Francis and Harwood (1985).

Regenerative agriculture was proposed by Gabel (1979) and further articulated by Rodale (1983) as an option that could lead to more sustainable agricultural production systems. This approach emphasizes the use of resources found on the farm instead of expensive imported energy resources, especially chemical fertilizers and pesticides. These contrasting sources of production inputs could be called "internal" and "external" resources (Rodale, 1985). The historical and conceptual bases for productive systems, summarized by Harwood (1983), need to include:

1. The inter-relatedness of all parts of a farming system, including the farmer and farm family,
2. The importance of the innumerable biological balances in the system, and
3. The need to maximize desired biological relationships in the system, and minimize the use of materials and practices which disrupt those relationships.

Harwood's tenets are similar to those cited by Boeringa (1980) and Youngberg (1984) for "alternative agriculture" and by Parr et al. (1983) for "organic farming." There have been several studies of reduced-energy, resource-conserving, sustainable production practices (Harwood, 1984b) and the economic consequences of their adoption (Harwood and Madden, 1982). We integrate these biological and economic components into a diagrammatic explanation of *progressive biological sequencing*, or how the choice of cultural practices can cause a dynamic change in the production environment. This conscious and directed

manipulation of individual fields by farmers through knowledge of biological interactions among species and the natural environment can lead to improved productivity. The combination over time of crops in several fields with animal enterprises can be called the *integrative structuring of the farming system*. We illustrate these concepts with specific examples of research results and observations from farms. These concepts and practices are ready for incorporation into Third World agricultural development strategies.

Realities of development

Problems that confront limited-resource farmers often involve a complex combination of climatic, biological, economic, cultural, and political factors (Francis, 1981). Limited land, high energy costs, inadequate availability of inputs and credit, distant and insecure markets, and political instability all contribute to the farmer's problems, most of which are beyond the control of the individual or family.

The apparent success of the Green Revolution in regions with a high level of resources has fostered the misleading assumption that science and technology alone can foster similar gains everywhere. One issue that could negate this assumption is the scarcity and long-term trend of increasing cost of fossil fuel energy. Because of the cost and uncertain availability of this external energy source, some development experts conclude that agriculture in many countries in the Third World is unlikely to ever effectively enter the fossil fuel era. Given the scarcity of fossil fuel-based inputs, we need to explore and develop alternatives in soil fertility and pest control both to produce more food and to protect the natural environment, including fish and wildlife (Youngberg et al., 1984). We especially need new approaches for medium and small sized farms in the Third World that are consistent with their limited resource base and the economic, social, and political realities of the farmer's environment (Office of Technology Assessment, 1984).

Macro-economic factors also affect the small farmer through lack of available production credit and high interest rates. Low resource farmers have limited access to capital to expand the farm or substantially change current farming practices. Investment in agriculture is often risky and produces limited return. World-wide concern about Third World indebtedness further reduces the opportunity for outside resources and raises serious questions about the high cost of current agricultural development strategies (Brown, 1985).

Given these realities, and given the growing body of information about biological systems and interactions among components of systems, *progressive biological sequencing* of crops can offer several advantages to farmers:

--Increased productivity, first for the benefit of the farm family, then respectively for the local community, for the region and nation, and for international markets;

--Maintenance or improvement of the productive potential of the soil; and

--Preservation and use of all production materials (nutrients, biocides, residues) within the farm boundary and in the upper layers of the soil profile, away from groundwater.

When several fields and their crop sequences are combined with the animal species that are a part of most small farms, the resulting *integrative farm structuring* can help the farmer:

--Make more efficient use of production resources on the farm;

--Integrate production activities on the farm into an efficient biological working system;

--Develop a more profitable and sustainable combination of farm enterprises, consistent with the family's goals and resource constraints; and

--Create a more healthful living and working environment.

Although priorities and practices may be different on certain farms in favored regions, decision makers need to recognize that most limited-resource farmers can work well and become more productive within the above guidelines. Small farm agriculture in most countries is unlikely to use scarce resources efficiently or provide stable food production unless development policies take account of farmers' needs and the constraints under which they must work. This in turn requires the development of a range of options for farms with different resource endowments.

Biological structuring

The complex ways in which all th plants and animals on a farm interact i their growth and development have bee called the "biological structuring" of th system (Harwood, 1984b). Unless en ergy and growth factors are transferre efficiently among niches within a sy tem, high and sustained yields can b achieved only through continuous an high applications of fossil fuel-based in puts, including chemical fertilizers an pesticides. High input systems, such a monoculture of maize, rice, wheat, an other cereal crops, are common in tem perate regions and have become th model for the Green Revolution in sub tropical and tropical areas where re sources are not limiting.

In contrast, organic agriculture o other alternatives take into accou more of the complexity of the total far environment, including the farm famil This is illustrated in the overview in Fi ure 1. More efficient biological stru turing takes advantage of th interactions and interdependenci among the components.

These interactions occur on sever levels: among the crops present in th same field at the same time; among th crops present sequentially in the sam field; and among the crops and anima in different parts of the farm and at di ferent times. For example, a three-cr relay system used by farmers in Easte Antioquia in Colombia includes pot toes planted in January, maize in Apr and climbing *Phaseolus* beans in Ju The potato crop is harvested in Ju when maize is hilled, and the maize an bean crops are harvested together in D cember or January. This intensive s quence of overlapping crops effective captures most of the light energy a rainfall during the entire year. A rel system of maize/sesame, maize/so bean, or maize/maize in the La Maqui area on the Pacific coast of Guatema takes maximum advantage of the seve month rainy season there in a way n possible with a single crop. Many a varied multiple cropping systems cu rently used by low resource farmers the developing world are based on be

eficial interactions among the crop components (Francis, 1986).

The interactions during a single season in one field are only a part of the dynamic interactions among crop components. The production environment changes over time, and the farmer can consciously alter and improve the field for subsequent crops through careful choice of crops and practices. The next section extends the view of what is happening in the field to include the time dimension. After that we discuss integration on the whole farm.

Progressive biological sequencing

A regenerative farming system is characterized by successive cycles of change in the crop and livestock production environment. Each wave of change usually results in an altered environment ideally suited to a different crop. The selection of a crop or combination of crops in each season and the sequence of crops and practices used over time in a field constitute a "rotation". This is both a reaction to those changes in the environment and a conscious influencing of them by the farmer. Environmental changes are both cyclical and linear. Their causal factors and results can be summarized in a diagram that illustrates the *progressive biological sequencing* of a system (Figure 2).

A crop both helps the farm family to meet annual production goals and changes the crop-associated microenvironment for succeeding crops. This is true whether it is grown alone, along with other crops in the same field, or in sequence with other crops. Planned cyclical changes in each field include shifts in weed species if crops are changed from one season to the next, population changes in soil-borne insects, and modifications of the soil nitrogen status. Although the farmer may not understand the basic biology of the system, experience and conventional wisdom have led to development of efficient sequencing. Long-term linear changes in the environment may include an improvement in soil physical properties, a net upward nutrient movement in the soil, a shift toward higher turnover rates of organic matter, increased and altered soil biological activity, and an increase in the labile fraction of soil organic matter.

This sequencing in a single field is illustrated by small farms in Taiwan, where most of the fields are planted to rice during the rainy season, and vegetables are transplanted into the rice straw after harvest. Three or more crop species may be produced in a given year on each small field. The choice of crops and management decisions appears to be influenced by specific goals of the family for the production from each field, as well as by the resources available for

Figure 1. Schematic overview of biological structuring in a regenerative farming system, showing crop/animal/family interdependencies.

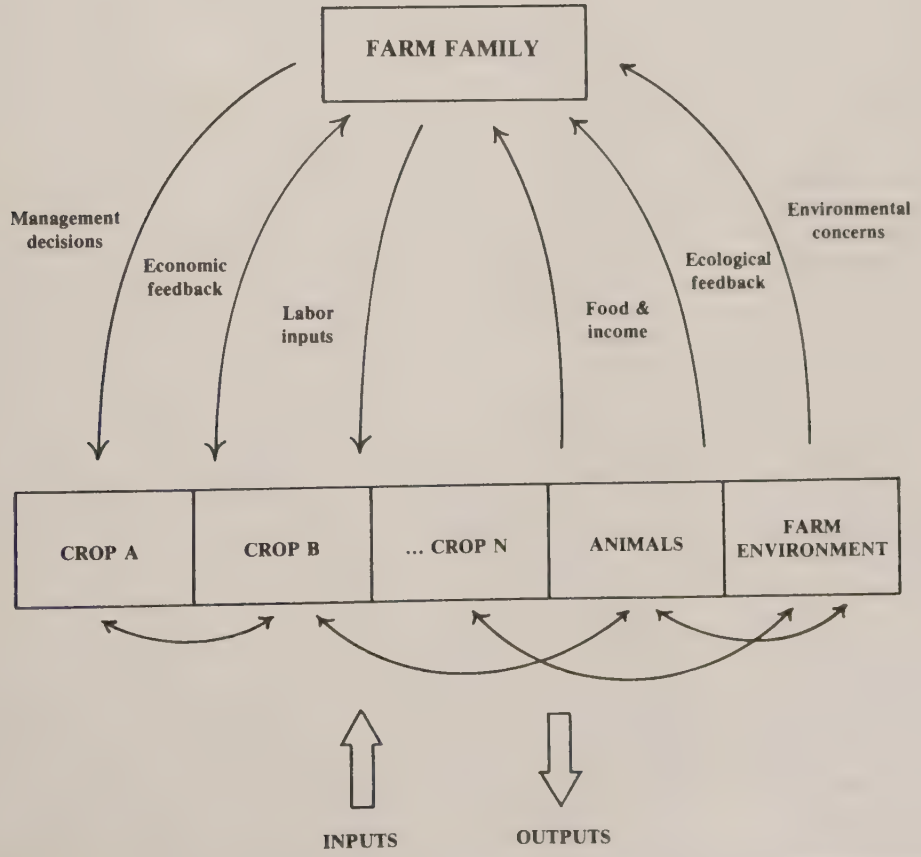
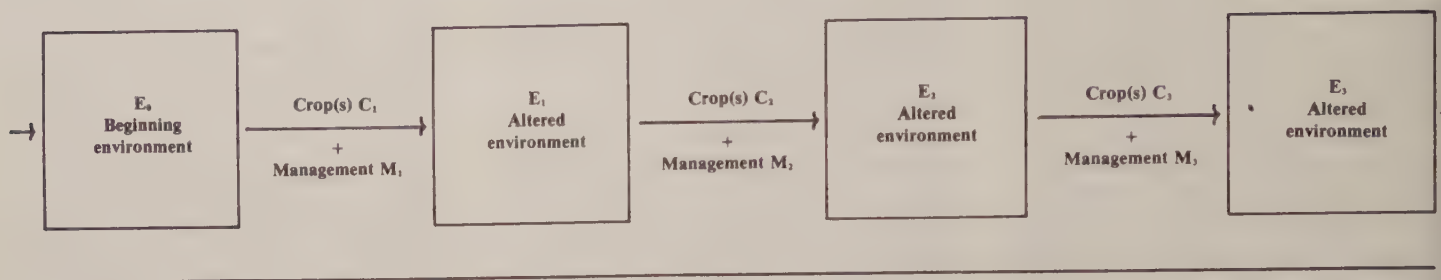


Figure 2. Conceptual pattern of dynamic cyclical and linear changes in one field crop environment as a result of successive crops and management decisions.



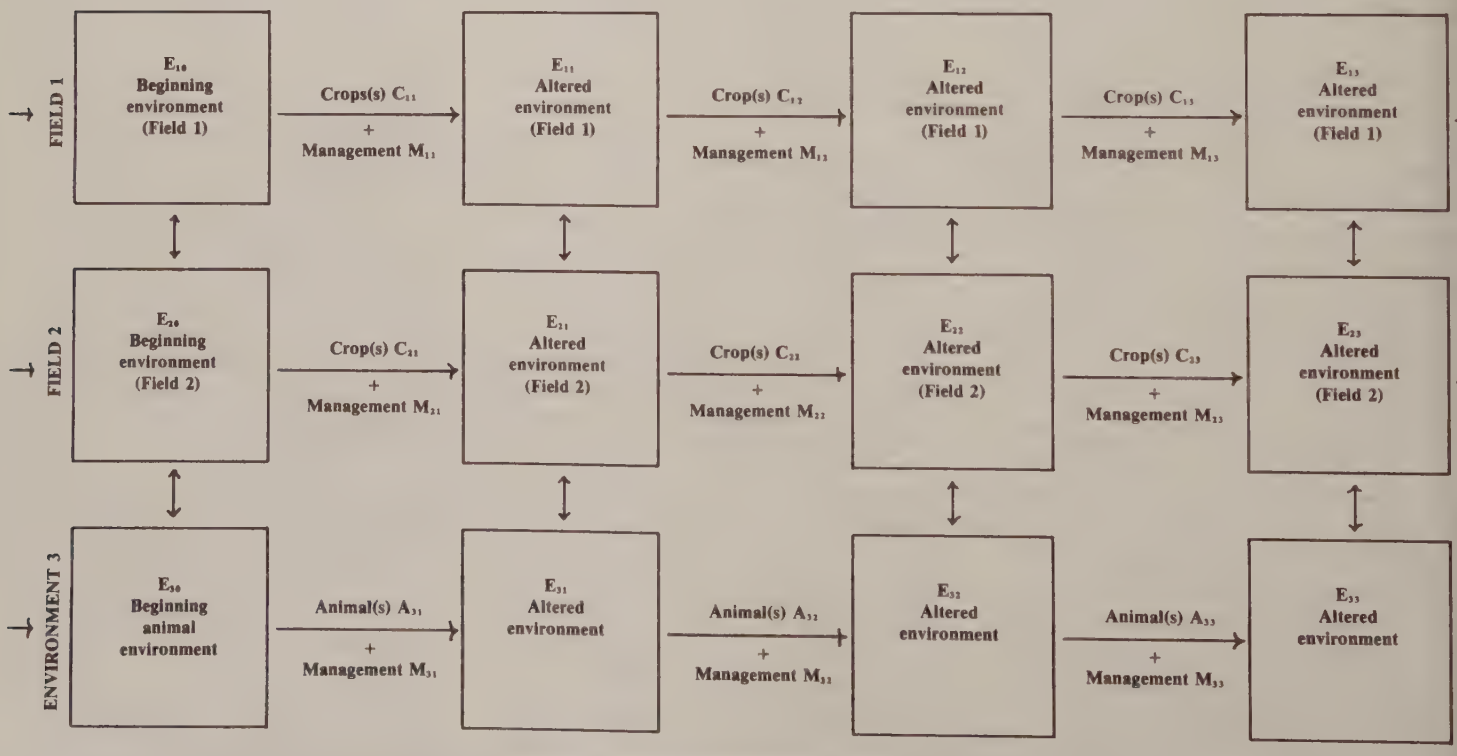
crop production. The field history probably is well-known to the farmer, and past experience will influence management strategy. Central to the decisions on input levels and crops will be the current status of the field environment, which in itself is a product of conscious structuring in this biological sequence. Yet decisions by the farmer may not be based entirely on what is most logical for each field, since a farm has several fields and other enterprises. The total management strategy must take into account the complexity of interactions, which require another dimension in the model.

Integrative farm structuring

When the biological structuring and interactions among the crops in a field are developed into a progressive sequence, cropping becomes efficient in resource use and in meeting the needs of the family. But interactions with the other enterprises on the farm also influence decisions on which crops to plant and how resources are to be distributed among the fields. If there is a conscio and rational combination of these acti ities on a farm, this could be called th *integrative farm structuring* that ties th farm together in its daily operation well as in long-term planning (Figure 3 If this structuring is done properly, will create an efficient distribution ar use of total available resources, inclu ing family labor. The result will be sustainable food supply and income f the family and an improvement or r generation of the soil productivity.

This structuring is illustrated by th

Figure 3. Conceptual pattern of interactions and integrations of primary crop and animal enterprises on a resource efficient farm.


INTEGRATIVE FARM STRUCTURING
FIELD 1
E₁₀ Beginning environment (Field 1)
Crops(s) C₁₁ + Management M₁₁
E₁₁ Altered environment (Field 1)
Crop(s) C₁₂ + Management M₁₂
E₁₂ Altered environment (Field 1)
Crop(s) C₁₃ + Management M₁₃
E₁₃ Altered environment (Field 1)
FIELD 2
E₂₀ Beginning environment (Field 2)
Crop(s) C₂₁ + Management M₂₁
E₂₁ Altered environment (Field 2)
Crop(s) C₂₂ + Management M₂₂
E₂₂ Altered environment (Field 2)
Crop(s) C₂₃ + Management M₂₃
E₂₃ Altered environment (Field 2)
ENVIRONMENT 3
E₃₀ Beginning animal environment
Animal(s) A₃₁ + Management M₃₁
E₃₁ Altered environment
Animal(s) A₃₂ + Management M₃₂
E₃₂ Altered environment
Animal(s) A₃₃ + Management M₃₃
E₃₃ Altered environment

total panorama of activities in the Taiwan situation where cole crops are transplanted into the rice stubble after harvest. They will be followed by at least one more vegetable crop before the next cycle of rice begins. Mushrooms are grown on the rice straw and, as the season closes, the residue from the mushrooms is brought back to the fields and spread for fertilizer on the next rice crop. Straw and other crop residues are fed to small animals kept near the houses, and both human and livestock wastes are brought back to the field as fertilizers.

The integration of activities among enterprises may be more subtle than the moving of residues or the application of manures as fertilizer. The decision to plant rice on most fields to provide a major source of income precludes the planting of other crops that might do equally well in the rainy season. Management of one crop that requires high levels of fertility may reduce the compost or manure available for another crop. Prices of production inputs and value of crops will vary from season to season and year to year, and this may influence management decisions and cropping sequences. Changes in livestock enterprises may require more or less feed for those animals -- thus affecting the decisions made for each field and for the integrated farm operation. Both political and social factors also can influence the management decisions by farmers with limited resources (Francis, 1981).

In summary, the basic idea is first to understand how the crops in each field alter the specific environment to make it suitable for a different crop or crops. Second, we have discussed how activities can be integrated into a structured model that underlies management of a complex farming system. The next step is to examine research results on specific components of technology, and to determine which of these are useful for the farmer who operates with limited resources. Some results from temperate regions have an application in the developing world. We explore how these fit into regenerative farming systems.

Cover Photo

The color photo on the cover, provided by Charles A. Francis of the University of Nebraska, shows an example of the intensive integrated cropping systems in Taiwan that are discussed in the article he co-authored with Richard R. Harwood and James F. Parr.

Specific technologies and systems

The right sequencing of crops and biological structuring of systems can save production inputs and achieve more sustainable production. For example, yields comparable to those in conventional chemical-intensive agriculture can be achieved at a lower energy cost in organic systems. A review by Pimentel et al. (1983) showed that organic wheat and corn production is 29 to 70% more energy efficient than comparable energy-intensive high technology systems. A number of such comparisons are discussed in the *USDA Report and Recommendations on Organic Farming* (USDA, 1980).

Culik et al. (1983) conducted an in-depth study of production practices, energy use and crop yields for a non-chemical farm in eastern Pennsylvania compared with conventional farms in the same region. Continuous maize production using recommended high technology such as fertilizers, pesticides, machinery and labor required more than twice as much total energy compared with a low-energy, non-chemical, biological-structured system. Thus, energy costs in maize production could be substantially reduced through crop rotations and other alternative practices. To be successful, reduced chemical systems may require a different type of managerial ability which can be gained primarily through knowledge of the biological structuring and interdependency among soils, crops, and animals.

Although fewer comparisons have been made in tropical regions, the reports summarized by Heichel (1973) for maize production in several countries illustrate a wide range of energy conversion efficiencies (units of energy produced per unit of energy invested). Most efficient are the slash and burn systems, where the only input is human labor for burning, planting, weeding, and harvest. These are followed by systems that are entirely based on human energy, where the output/input ratio is between 10 and 19. At the other end of the spectrum are present day systems that depend on heavy investment in fossil fuels, with a ratio of 3 or 4. These latter systems are the most productive per unit of labor and, in some cases, per unit of land area.

Principal integration efficiencies of cropping systems were summarized by Harwood (1984b). The ways in which crop components complement or compete with each other in resource use will influence the success of a specific sequence of crops. Some of the biological processes that promote these efficiencies include nitrogen fixation, nutrient cycling and management, disease suppression, insect population effects, and weed cycling. Because of these structural or integration efficiencies, moderate to high yields can sometimes be maintained without continuous infusion of energy-intensive production inputs.

Nitrogen fixation: In the temperate zone, forage legumes can contribute from 25 to 50% of the nitrogen needed in most cropping systems, but meeting the total N requirement through symbiotic fixation would be difficult with current technology according to Heichel and Barnes (1984). Vogtman (1984), however, presented data indicating that nitrogen self-sufficiency in regenerative or alternative agriculture is achievable. Moreover, Kaffka (1984) in his detailed study of a German dairy farm, substantiates this conclusion. Current methods and techniques for measuring the amount of nitrogen fixed by legumes and available for subsequent crops may underestimate the potential contribution of fixation (La Rue and Patterson, 1981).

Data from the Rodale Research Center (Harwood 1984a) suggest that it is possible to meet the total nitrogen needs of a cereal crop from legumes in rotation. The Kutztown farm, operating with minimal inputs from outside the system for 10 years, has consistently obtained yields of wheat and maize that are substantially above county averages. Wegrzyn (1984) studied nitrogen balance in maize grown for three years following alfalfa and measured no response to added nitrogen during that time. Thus, the current contributions and potential future improvements anticipated

in biological fixation are vital to regenerative or alternative agriculture because they can enable farmers to greatly reduce chemical N fertilizers (Alexander, 1984).

Alternative methods are available for maintaining soil fertility in tropical regions as summarized by Liebhardt et al. (1985). Mixed cropping systems including a cereal and a legume were shown to be 38 to 55% more productive than monocultures in Uganda, although the fertility contribution of the legumes could not be singled out because it was confounded by other factors (Osiru and Willey, 1972; Willey and Osiru, 1972). In Trinidad, Dalal (1974) studied maize/pigeonpea (*Cajanus*) intercrops, including detailed measures of total dry matter and nutrient uptake. Total nutrient extraction was consistently greater for the mixture compared to monoculture. More research is needed in the important area of soil fertility, since nitrogen is especially critical for the growth and production of cereal crops. Critical areas for future research were suggested by Barker and Francis (1986).

Nutrient cycling: In a conventional cropping system that uses fertilizer nitrogen and deep inversion tillage (e.g. moldboard plow), the flow of this nutrient is into the crop and down through the soil profile, where it may be totally lost to the crop and become a groundwater pollutant. The long-term effects of this process on groundwater quality in Iowa have been described by Hallberg (1984). In a well-structured system that depends on organic sources of nitrogen and shallow, non-inversion tillage, there may be a net upward movement of nitrogen and some other nutrients.

If roots of several component species exploit different soil strata, total nutrient uptake may be greater (Liebhardt et al., 1985). When deep-rooted and shallow-rooted species are grown together, the deep-rooted plants can capture nutrients that are leached past the roots of the shallow-rooted plants. These nutrients are converted into leaves and other plant material and again deposited on the surface. The difference in nutrient movement in organic compared with conventional systems was suggested by Howard (1947) and has been confirmed by Patten (1982).

The following practices are common to regenerative or alternative farming systems and can promote a net upward movement of nitrogen and other nutrients in the soil profile (Harwood, 1984b):

--The crop rotation must include deep rooted crops;

--Use of highly soluble nutrient sources must be avoided;

--Use of a disk or chisel plow, or minimum tillage, should replace the moldboard plow;

--Nutrients added to a system should be put on sod crops to maximize nutrient uptake;

--Seasonal use of cover crops directly following major cash crops should enhance the uptake and recycling of soluble nutrients; and

--Crop residues should be maintained largely at or near the soil surface to minimize erosion, reduce soil crusting, and decrease evaporative water loss.

Such systems should significantly reduce plant nutrient losses by promoting their cycling through living plant tissue and retention in crop residues and soil organic matter. This would minimize the need for additional nutrient inputs, although more information is needed on these interactions in low-input cropping systems. Cycling in these cropping systems would be similar to what occurs in natural climax forest communities, and there is much to be learned from recent research on agroforestry systems (Keya, 1974; Kock, 1982; MacDonald, 1982; Sanchez, 1976). A long-term goal is to approach the closed nutrient loops defined by Edens and Haynes (1982) for the farming systems of the future.

Integrated nutrient management: The low-resource farmer needs alternative ways to restore and maintain soil fertility with a minimum of external inputs and costs. One such alternative is proper utilization of on-farm sources of crop residues and manures (FAO, 1975; USDA, 1980). Proper crop sequences and well-designed intercrops of cereals and legumes can improve soil physical structure, fertility, and total productivity, which in turn could lead to increased crop yields and greater net return. Deep-rooted crops can recover some plant nutrients from lower soil depths, where they might otherwise be totally lost from the system, and make them available for current or succeeding crops. Overseeding legumes into a growing crop, or providing a legume cover during a fallow period, can produce up to 100 kg/ha of nitrogen in a few months (Heichel and Barnes, 1984; Liebhardt, 1983). Maintaining substantial amounts of nitrogen and other nutrients in organic form during periods when crops are not grown can help reduce nutrient losses through leaching and erosion.

Integration of animals into the total system is another option. Use of manure converts a waste product into a resource that can improve soil fertility, as illustrated by two reports from Tanzania (Ngaiza, 1983; Samoka et al., 1983). Obviously, the animals also are a source of food and income for the family. The incorporation of woody legumes into cropping patterns such as alley cropping (planting of annual crops between rows of leguminous trees spaced two to five meters apart) could provide substantial amounts of fixed nitrogen for a non-leguminous crop, a canopy for protecting the crop and minimizing soil erosion, and a source of fuel and fodder (Office of Technology Assessment, 1984).

Disease suppression: Crop rotations often reduce soil-borne diseases (Harwood, 1984a). The mechanisms are not well understood but appear to be related to the soil's high organic matter content and high level of microbiological activity and to the diversity of crop species grown in sequence. Some of the steps that might promote disease suppression include:

--No one crop species should be grown in the same field more frequently than every five years;

--Processed compost or manure should be incorporated into the soil each year to maintain soil physical properties and fertility; and

--Residues from crops that may contain harmful pathogens should be buried after each harvest.

A better understanding of disease suppression could make integrated management and non-chemical control of soil-borne diseases more practical. Gliessman (1980) and Altieri and Liebman (1986) review examples of reduced diseases in multiple cropping systems and speculate on some of the mechanisms that might be involved.

Insect population effects: Organic systems sometimes have lower levels of

damaging insects. This may be due to higher levels of predatory insects, parasites, and antagonistic microorganisms compared with conventional chemical systems (Karel et al., 1983). Among the practices used on non-chemical farms to reduce damaging insect populations are crop rotations, diversity both within the field and in border strips, different forms of multiple cropping, and border strips between fields. Motyka and Edens (1984) compared an organic onion farm with two conventional onion farms and found a higher insect species diversity in the former. There were also fewer onion flies reported on the organic farm than on conventional farms using chemical control. The benefits of multiple cropping systems to reduce insect populations were summarized by Altieri and Liebman (1986), who found that most reports supported this hypothesis. Diabrotica beetles in (*Phaseolus*) beans and fall army worms (*Spodoptera*) in maize were both significantly reduced in bean/maize intercrops in Colombia, compared to nearby monoculture plots (Altieri et al., 1978). Cultural control of insects could significantly lower production costs and minimize a farmer's dependence on chemical pesticides. It can also reduce exposure of people to chemicals and contamination of food chain crops.

Weed cycling: Cropping cycles can significantly control weeds without chemicals by inhibiting the growth and development of individual weed species. Alternating field conditions such as flooded crop/dryland crop or cereal crop/legume crop in the tropics and winter species/summer species or annual crop/perennial hay crop in the temperate zone can all provide a contrasting series of environments that prevents the build-up of weeds that are better adapted to single crop systems. A summer annual cereal followed by a hay crop is an example of a sequence where different weed species prevail in each crop. Because this crop sequence is counter-cyclical to the weed species development, it often can provide satisfactory control without expensive chemicals. Suppressive crops such as buckwheat, sorghum-sudan hybrids, or oats can be used in rotations when weeds are severe in temperate cropping systems.

Multiple cropping systems have also been shown to compete successfully with weeds. This has special relevance in the developing world because farmers cannot always depend on herbicides (Akobundo, 1980; Walker and Buchanan, 1982; Altieri and Liebman, 1986). In Tanzania, many of the most noxious weeds can be controlled by a combination of cultural methods and chemical control (Minjas and Jana, 1983). Preventive measures include use of clean crop seed, well-decomposed manure, and clean equipment (Minjas, 1978). To design effective weed management strategies, more information is needed about weed growth and cycling in tropical climates, particularly as affected by soil conditions and crop/weed interactions.

Yields and yield stability: Crop yields depend very much on the management skills of the farmer in both conventional and alternative or regenerative systems. On the average, yields in highly-structured, non-chemical farming systems range from higher to as much as 10% lower than in conventional systems in temperate zones (Parr et al., 1983). Production costs and energy inputs may be up to 40% lower in the non-chemical systems, although labor and management costs may be higher (USDA, 1980). A livestock farm in Pennsylvania (Culik et al., 1983) and a prairie wheat farm in Washington (Patten, 1982) (the latter having used regenerative or alternative agricultural practices for 70 years) offer examples of stable yields without chemical inputs to maintain soil fertility or control pests.

Examples of biologically structured systems in the tropics include the potato/maize/bean system in Antioquia, Colombia, and the maize/sesame or maize/soybean system used on the Pacific coast of Guatemala. Greater stability of yield in bean/maize intercrop systems in Colombia (Francis and Sanders, 1978) and in sorghum/pigeonpea intercrop systems in India (Rao and Willey, 1980) further illustrates the advantages of multiple species systems that are well structured. Both sequencing of crops within a field and the combinations of crop and animal enterprises on the whole farm illustrate the application of the principles of progressive biological structuring and integrative farm structuring.

Contributions of conventional research

There is a substantial store of research on conventional systems that can be directly applied to regenerative agriculture. Crop yield responses to fertility, to density, and to pest losses will be relevant under a wide range of management systems. Likewise, the crop varieties and hybrids that are well adapted to a given environment likely will perform well in another management system in that same region, although there may be interactions of genotype with cropping system when management is changed drastically (Smith and Francis, 1986). The contribution of conventional research to these structured systems is illustrated with three examples: use of organic wastes, integrated pest management, and genetic improvement of crops.

Utilization of organic wastes: Developing countries have traditionally used organic materials, such as animal manures, crop residues, and green manures and composts, to maintain or improve the productivity, physical structure, and fertility of their agricultural soils. With the publicity and promise of the Green Revolution in the 1960s, organic recycling practices on some farms were largely replaced with chemical fertilizers. At that time, these chemical products were relatively inexpensive and easily obtainable, and they often produced dramatic yield increases. Consequently, proper use of organic matter in maintaining soil productivity was neglected. As a result, the agricultural soils in some areas have undergone extensive degradation because of excessive soil erosion, nutrient runoff losses, and depletion of soil fertility.

The world energy crisis that began in the early 1970s and global food shortages around the same time resulted in the sharply increased cost and uncertain availability of chemical fertilizers in many developing countries. Not surprisingly, the 1974 World Food Conference in Rome passed a strong resolution calling on the Food and Agriculture Organization (FAO) of the United Nations to initiate programs and workshops that would emphasize the value and importance of organic wastes as fertilizers and soil amendments, and to reintroduce both established techniques and new

practices for their effective utilization on agricultural land (FAO, 1975; Parr and Papendick, 1983). As a result, many countries have requested information and appropriate technology for recycling organic wastes, both from on-farm and off-farm sources. There has been strong and renewed interest in composting technology for two principal reasons. First, the process resolves many of the problems associated with various organic wastes (including animal manures, nightsoil, sewage, and sludge), such as odors, human pathogens, and storage and handling constraints. Second, composting produces a stabilized form of organic matter that has a greater residual effectiveness for improving the physical structure and productivity of soils (Parr and Papendick, 1983; USDA, 1978). The U. S. Department of Agriculture has developed a highly successful aerated pile method for rapid composting of sewage sludge, animal manures, municipal refuse, and pit latrine wastes (Willson et al., 1980). Several developing countries have adapted this technology, which is simple, relatively inexpensive yet effective, and flexible in allowing considerable trade-offs between labor and capital.

Developing countries generate substantial amounts of various organic wastes that could be composted and made available at a nominal fee to farmers who need off-farm sources of organic matter to improve the soil structure and productivity of their lands. National governments should conduct surveys of the types, amounts, and availability of different organic wastes that could be used for this purpose (Parr and Papendick, 1983; USDA, 1978).

Integrated pest management: Appropriate strategies using integrated pest management (IPM) build on the efficiencies of a well-structured biological system to provide internal control of most pests. In contrast to the expense, danger, and long-term consequences that may accompany the use of conventional chemicals, IPM uses knowledge about the crops and pests to design strategies to manage and reduce the impact of weeds, insects, and pathogens, rather than to eradicate them. Combining resistant or tolerant crop varieties, rotations of crops that are dissimilar in growth habit and resource use, effective management of crop residues, and encouragement of natural predators and parasites can all lead to adequate control of pests without the costs and risks of heavy chemical applications (Luckmann and Metcalf, 1975).

Exploiting genetic potentials of crops: An important research challenge is to develop plant species that can make maximum use of limited levels of water and nutrients. Combined with new approaches to provide fertility, it will be invaluable if plants have the genetic ability to efficiently use whatever nutrients are either supplied externally or are present in the soil profile. Insect and disease resistance or tolerance and an ability to compete successfully with weeds early in the crop cycle are also important.

The genetic code carried in the seed is especially valuable to the farmer with limited resources, since this is potentially one of the least expensive inputs that can be purchased for a large area. In crops like beans, potatoes, soybeans or wheat the farmer can carefully select and save seed for the next season. This can also be done if new maize or sorghum varieties are the result of a cross between two variable parent lines, and if the new variety can be grown in sufficient isolation to maintain its genetic identity.

A recent paper by Jain (1985) points out that grain yield increases for wheat in the United States, United Kingdom, and India have resulted from a reduced plant height and increased harvest index (i.e., ratio of grain to total dry weight). For the last 75 years, grain yield increases have often been associated not with any significant increase in the biological yield (ie. total dry matter production), but rather with a higher proportion of grain. There is some doubt that the harvest index can be increased much more, and maximum levels may already have been reached for some crops. The key to further increasing the yield of most cereal crops, as well as grain legumes, depends on increasing the biological yield. This in turn could be partitioned to divert more photosynthate into the grain. A high priority for biotechnology is to genetically induce these plants to fix more carbon.

Improved crop quality is an additional priority when breeding crop varieties for home consumption or sale. Genetic engineering may provide the increased efficiencies outlined above, as well as enhanced grain quality and better insect and pathogen resistance. Yet manipulation of the genome is only a first step in a long series of activities. Selection and testing in the field are also required before release of a new variety, and genetic engineering provides no quick-fix panacea for solving all the complexities and time needed in plant breeding. Preservation of genetic resources for future generations, as well as providing access for all countries to the materials developed in national and international programs, is important to improving production. A favorable environment for exchange of ideas and germplasm needs to be fostered in the international community.

Conclusion -- farmer self reliance

When specific technologies applied in a well-structured cropping sequence reduce the farmer's dependence on external inputs, management is less determined by externalities over which the farm family has little control. Given what is known about the biological efficiencies of alternative cropping sequences and management, the farmer can adopt regenerative technologies that produce yields similar to those of conventional systems, but with substantially lower production costs. The farmer can implement these practices partly by substituting knowledge or new information for what was previously purchased to grow the crop, as we have illustrated in the earlier examples. When family labor is available, there is an advantage to intensive crop management, and in some cases there is a comparative advantage in these systems for the operator of a small or medium sized farm. The self reliance that can be developed by the limited resource farmer can lead to greater food and income security.

Governments and bilateral/international assistance agencies can help farmers achieve this self reliance by developing a broader range of regenerative, organic, or other alternative resource-efficient technologies. Strategies can be designed at the national level that encourage local autonomy and self reliance, although these are quite a de-

parture from most development approaches in vogue today. An improved understanding of traditional farming systems and their complex biological components opens up different approaches for limited resource farmers through efficient farm structuring.

Food production for local and national consumption needs to have priority in a total development strategy. Governments can encourage production of basic food commodities through import and export policies, realistic price supports, and by incentives for farmers to increase production. International and bilateral programs also need to support this decision. Thus, the government's policies can promote a degree of self reliance at the national level, and can foster the same objective at the local level.

Technology that improves soil fertility and pest control using internal resources needs to be developed and tested on the farm. This could build toward increased local stability of production and eventually greater national security in the basic food supply. The use of internal inputs for agricultural production reduces costs for transportation, eases complications of a poorly developed infrastructure, and increases self-reliance in each region.

Regenerative farming systems provide one approach that could improve both the production potential of the soil and the environment in which the farm operates. By reducing or eliminating use of chemical pesticides and external sources of fertilizer, non-chemical methods could help increase the biological potential of the soil environment. Implementation of some practices described above could help countries to become more self-reliant in food supply through a rational use of natural resources. Tomorrow's development strategies will be characterized by a range of options for farmers, and by a more efficient use of scarce production resources in agriculture.

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Maine study identifies soil-improving wastes

The Maine Department of Agriculture has published a report on waste products in the state that have value as agricultural soil amendments. The 13 waste products inventoried and described range from paper mill sludge to cheese whey.

In addition to providing the volume and location of each waste product, the 170-page report includes information on physical and chemical characteristics, suitability as a soil amendment, best handling methods, and farm use constraints. Copies of *Usable Waste Products for the Farm* are available on request from the Division of Resource Management, Maine Department of Agriculture, State House Station 28, Augusta, ME 04333.

Oil-related agriculture problems predicted

A report described as the first detailed comprehensive effort to predict U.S. oil-related agriculture problems well beyond the year 2000 has been published. Projections based on computer analyses indicate producers may face such high energy costs early in the next century that the United States will be unable to continue as a net exporter of agricultural products.

The 304-page volume is based on a 3-year study sponsored by Carrying Capacity and carried out by the Complex Systems Research Center at the University of New Hampshire. Copies of *Beyond Oil: The Threat to Food and Fuel in the Coming Decades* is available for $14.95 postpaid from Carrying Capacity, 1325 G St., N.W., Washington, DC 20005.

Organic directory is published in California

A directory listing more than 200 organic food wholesalers and distributors and more than 100 suppliers of biological pest controls and other organic farming inputs has been published by the California Agrarian Action Project.

The directory has listings from 32 states and Canada and is designed to help make connections between organic farmers, wholesalers, and suppliers. *1986 CAAP Directory: Wholesalers of Organic Produce and Products* is available to non-members for $26.75 postpaid from CAAP, P.O. Box 464, Davis, CA 95617.

OTA issues major farm technology report

The Congressional Office of Technology Assessment (OTA) has issued a major report that analyzes the likely impacts of biotechnology and information technology on agriculture between now and the year 2000. It focuses on the relationship of technology to production, farm structure, rural communities, resource conservation, credit, research and extension, and public policy.

The 374-page report identifies and describes 150 production technologies likely to become available commercially to shape and define agriculture over the next 15 years. Copies of *Technology, Public Policy, and the Changing Structure of American Agriculture* are available for $13 from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Environmental education guide is available

A guide to environmental programs offered by 95 colleges and universities in New England has been published. In addition to listing a faculty contact and describing the environmental curricula offered, the guide covers internship opportunities, research and fieldwork facilities, and associated environmental organizations.

Single copies of *A Guide to Environmental Programs in New England Colleges & Universities* are available on request from the New England Environmental Network, Lincoln Filene Center, Tufts University, Medford, MA 02155.

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Income effects of limiting soil erosion under organic, conventional, and no-till systems in eastern Pennsylvania

Jean L. Domanico, Patrick Madden, and Earl J. Partenheimer

Abstract. *A 294-acre Pennsylvania crop and livestock farm was modeled under alternative management practices using linear programming. The management practices included conventional, organic, and no-till production, with and without the use of overseeding and cover crops. For each of the management practices, soil erosion was estimated using the Universal Soil Loss Equation. Profitability was compared across the options with and without constraints on soil erosion. Prior to constraining soil erosion, no-till was found to be the most profitable option. The conventional option was next most profitable, followed closely by the organic option. The use of cover crops or overseeding was found to be unprofitable when high levels of soil erosion were allowed. When soil erosion was constrained, the relative profitability of the options changed. It was found that practices that can control erosion with the least reduction in the intensity of rotation, such as planting cover crops, overseeding and no-till, are the most profitable options when soil is constrained to below 5 tons per acre. No-till remained the most profitable option at low levels of soil erosion. The economic advantage of conventional over organic production diminished as soil erosion was constrained. Below 5 tons per acre of soil erosion, the organic system became more profitable than the conventional system. It was found that use of overseeding or cover crops makes a more profitable rotation possible at low levels of soil erosion.*

Purpose and scope of study

Concern about the problem of soil erosion has been widespread in the United States since the 1930s (ASA, 1982). Soil erosion decreases the productivity of fields where the topsoil is shallow above an infertile subsoil or solid rock profile by reducing organic matter, nutrient supply, water infiltration, and soil water-holding capacity. Additional nutrients, organic matter and water may be necessary to maintain yields on eroded land. Advances in agricultural technology often mask the yield-reducing impact of soil erosion (Crosson and Stout, 1983, p. 59).

Soil erosion from farmland also causes serious externalities, including off-site environmental problems (Crosson, 1982, p. 183; Crosson and Stout, 1983, p. 17). Particles of soil transported by water are deposited in streams, harbors and reservoirs, increasing the risk of floods, impeding navigation, and reducing water storage capacity. In addition to clogging waterways, suspended soil particles act as carriers for agricultural chemicals. Most chemical pollutants removed from farmland by runoff are carried by eroded soil, with chemical molecules adsorbed on clay particles (McCormack et al., 1982). When the land user is not held accountable for such external costs, they costs are transferred to people in other places or future time periods (Timmons and Amos, 1982).

In addition to the problems created by soil erosion, there are other reasons for concern about the sustainability of our current system of agriculture. The extensive use of chemicals in agriculture today has raised concern in the areas of energy, health and the environment (Lockeretz et al., 1975).

Technology is needed to help reduce these problems in ways that would not be financially ruinous to farmers already under considerable stress. If profitable alternatives to highly erosive and chemical-intensive farming technologies could be found, these problems could be overcome with a minimum of financial sacrifice by farmers and without recourse to burdensome regulations or punitive actions by the state. Although research in this area has been limited, alternative technologies do exist. The purpose of this study is to develop a model of a Pennsylvania crop and livestock farm that can be used to evaluate several alternative farming systems with regard to income and erosion control. Specifically, the objectives are to:

1. Construct a computer simulation model of an existing Pennsylvania crop and livestock farm.
2. Determine the trade-offs between soil erosion control and income for several management options on the model farm, including conventional, no-till, and organic systems, with and without overseeding of legumes into corn (Domanico, 1985).

Previous studies

This study builds upon the findings of previous studies in two substantively distinct areas: (1) the trade-offs between erosion control and income, and (2) the economic feasibility of organic farming methods. Several studies have been conducted in the United States on both topics. Many studies of the financial trade-offs in soil erosion control have concluded that controlling soil erosion reduces current farm income. Even those studies that took into account reductions in income from decreases in soil productivity over the long run found that there is little incentive for the profit-

Jean L. Domanico is Research Assistant and Patrick Madden and Earl J. Partenheimer are Professors of Economics in the Department of Agricultural Economics and Rural Sociology, Pennsylvania State University, University Park, PA 16802.

maximizing owner-operator to limit soil erosion. These studies found that reductions in income associated with reducing soil erosion were largely due to substitution of less intensive, less profitable rotations for more intensive, more profitable rotations. Methods for controlling erosion that had the least harmful impact on income were those that did not require substitution of forages for row crops (Crowder et al., 1984; Harker and Michalson, 1976; Krog et al., 1983; Nelson and Seitz, 1979; Swanson and Harshbarger, 1964; Swanson and Maccalum, 1969; White and Partenheimer, 1979). The present study builds upon the conclusions of earlier work by including options, such as overseeding and no-till, which do not require a less intensive cropping system.

Use of the term "organic farming" in the literature frequently follows the USDA definition (USDA, 1980, p. 9):

"Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manure, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests."

Numerous studies on the feasibility of organic farming have found the value of crops produced to be lower for organic farms than for conventional farms. This was due to slightly lower yields and a greater substitution of forages for high-value row crops on the organic farms. Costs of production were found to be lower on organic farms, however, and organic farming practices were found to be superior for controlling soil erosion, minimizing water pollution, and conserving energy. From these studies one can conclude that organic farming systems may be, under some circumstances, an economically viable strategy for reducing the harmful environmental impact of some types of farming (Klepper et al., 1977; Lockeretz et al., 1975; Lockeretz et al., 1984; Shearer et al., 1981; USDA, 1980; Vogtmann, 1984).

In the studies comparing groups of organic farms to groups of conventional farms, accounting for all systematic differences between the groups other than differences being studied was a problem. An ideal method of comparing the profitability of organic and conventional methods would be to compare two farms that differ with regard to the use of organic or conventional methods, but are identical in all other respects. Finding matched pairs of organic and conventional farms that are identical in size, location, physical characteristics, and management levels would be impossible. Mathematical programming techniques including computer simulation and linear programming optimization can provide a practical though still imperfect method. With the use of a computer simulation, the profitability of chemical-intensive conventional systems and organic systems can be compared for the exact same farm, under alternative assumptions as to the permissible levels of soil erosion.

The simulation model

Since the primary goal of this study is to compare the profitability of several farm management options subject to alternative limits on soil erosion, linear programming is an appropriate method. Since the 1950s, linear programming (LP) has become widely used as a research tool in agricultural economics. It is often used to find profit-maximizing farm plans and to formulate least-cost feed mixes (Doll and Orazem, 1984). LP is very flexible. The model developed for the present study selects the combination of crops that earns the highest net returns over cash operating costs, while restricting the overall soil erosion on the farm to less than an assumed level. The model is run repeatedly, assuming successively lower levels of soil erosion, to determine the trade-offs between the current year's income and current rates of soil erosion.

The simulation was based on an actual 294-acre mixed crop-livestock farm located adjacent to the Rodale Research Center near Kutztown, Penn. Data on the Kutztown farm were available for this research because of a study conducted by the Rodale Research Center from 1978 to 1982. This data base provided information on crop mixes, yields, production costs, and physical charac teristics of the farm (Culik et al., 1983 In constructing the various versions o the model, data from the actual farm were used whenever possible.

The Kutztown farm has been oper ated with minimal use of chemicals sinc 1972. For the most part, weeds are con trolled with cultivation and nutrients ar supplied by manure applications and ro tations with legumes. Conventional til lage with spring plowing and contou strip-cropping are used. The mixture o crops produced on the farm includes ap proximately one-third row crops (corn and soybeans), one-third hay, and one third small grains. Four types of grai are grown in equal proportions on th small grain land because of the persona preference of the farmer.

The primary activity for the mod farm was to produce feed for finishin 213 head of beef cattle, as is typicall done on the Kutztown farm. The mod allowed a variety of crops to be produce and chose the least-cost mixture of crop to feed the cattle. The nutrient requir ments for cattle were based on Nation Research Council (1976) recommend tions for Total Digestible Nutrien (TDN), Digestible Protein (DP), an Dry Matter (DM). Additional crop were sold off the farm. The three so types found on the Kutztown farm which have varying degrees of erosivit were represented in the model and th Universal Soil Loss Equation (USLE was used to estimate soil erosion for th various crop producing activities. Alte ations were made to this basic model t allow it to represent alternative man agement systems.

Eleven versions of the linear program ming model were created. ORG, ORG ORG2, and ORG3 are the organic ve sions. ORG represents the Kutztow farm approximately as it is current being operated with minimal use o chemical inputs. The ORG model re quired equal acreages of four sma grains (wheat, barley, rye, and oats) t be planted on the small-grain portio (one third) of the cropland, as is th practice on the Kutztown farm. ORG is identical to ORG, except that th model is permitted to select the mo profitable combination of the four sma grains (it chose wheat). ORG2 requir that only enough small grains are pr

duced to meet the straw bedding requirement, rather than requiring one-third of the land to be in small grains (it reduced the acreage of wheat). ORG3 has no small grain requirement; the model is allowed to purchase straw rather than growing it on the farm as small grain crop residue (it purchased all the straw except the amount resulting from wheat used as a nurse crop for establishing a new stand of alfalfa). ORG1+OS, ORG2+OS, and ORG3+OS were the same as ORG1, ORG2, and ORG3 but with overseeding of clover into corn. Corn production costs and soil erosion estimates were adjusted accordingly. For the organic versions, conventional tillage with spring plowing and contour strip-cropping were assumed, consistent with present practices on the Kutztown farm.

The Rodale Research Center has been conducting research on overseeding a legume into established corn during the final cultivation. The legume germinates and becomes established before the corn canopy closes. After the corn is harvested, the sod remains as a cover crop through the winter and is incorporated into the soil the following spring. Some of the benefits from this system include erosion control, increased water holding capacity, higher organic matter content, and increased nitrogen available for the following crop (Hofstetter, 1983). The overseeding experiments were conducted without the use of chemical pesticides or herbicides. The best results were obtained with medium red clover (*Trifolum pratense* L.) seeded at 12 pounds per acre. Corn yield was not adversely affected by this procedure (Culik, 1984, personal communication).

Conventional and no-till versions of the model were also created. CONV represents the farm under conventional production practices with chemical fertilizers and pesticides and no requirement for rotation. As in the organic versions, conventional tillage with spring plowing and contour strip-cropping are assumed. CONV+OS adds overseeding to the conventional version. NO-TILL assumes no-till production practices and NO-TILL+CC is analogous to the overseeding options of ORG and CONV, except that the clover is planted as a cover crop.

As was previously mentioned, data from the Kutztown farm were used whenever possible in constructing the versions of the model. When data from the farm were not available, assumptions were made after consultations with experts at the Rodale Research Center and Pennsylvania State University. For all versions of the model, the Universal Soil Loss Equation was used to estimate soil erosion (Wischmeier and Smith, 1978, p. 26):

$$A = R \times K \times (LS) \times C \times P$$

where: A = soil erosion in tons per acre
R = rainfall and runoff factor
K = soil erodibility factor
LS = factor dependent on length and slope
C = cover and management factor
P = support practices factor

The cover and management factor, C, depends on the type of crop, the intensity of rotation, and the tillage practice used. This was the only factor to vary over the versions of the model. All of the other factors, based on data from the Kutztown farm, remained constant across all versions of the model.

For all of the organic versions of the model, costs of production were calculated from data collected by the Rodale Research Center on the Kutztown farm (Culik et al., 1983). As part of the Rodale Research Center study, budgets were also calculated to represent the costs and returns that would have occurred if conventional farming practices had been used. These conventional budgets included the costs of chemical fertilizers and pesticides. The assumed rate of fertilizer application was based on 1982 soil analysis and conventional fertilizer recommendations for the farm. In all versions of the model, it was assumed that the manure from the farm's beef cattle was applied to the fields. The pesticide costs were based on the Farm Management Handbook recommendations (Dum et al., 1977). These budgets were used to construct the conventional versions of the model. Costs of production used in the no-till versions were adapted from the Penn State Agronomy Guide (1985-86). In all versions of the model featuring overseeding or a cover crop of clover, soil erosion estimates were reduced and costs of production for corn were increased to cover the costs of establishing the clover.

The Rodale Research Center Study provided the selling prices for the crops produced on the farm for 1982. For the purposes of this study, all input prices and selling prices were adjusted to five-year averages to moderate the effects of abnormal prices during a single year (Domanico, 1985, p. 96-97).

The crop yields assumed in the organic versions of the model were based on measured yields from the Kutztown farm. These yields were somewhat higher than state and county averages (Culik et al., 1983, p. 43). Wegrzyn (1984, p. 28) reported that the corn grain yield on the most fertile fields of the Kutztown farm in 1978 was 99.6 percent of the county's highest "Five Acre Corn Club" yield, which was based on chemical-intensive practices.

The sources of soil nutrients differed among the various options. For the organic options, it was assumed that legumes in the rotation plus feedlot manure and some purchased chicken manure provided virtually all the added nutrients. A minor amount of liquid starter fertilizer was also used, providing about 4 pounds of N and K_20 and 7 pounds of P_2O_5 per acre (Culik et al., 1983, p. 47; Wegrzyn, 1984, p. 40). For the conventional and no-till options, it was assumed that roughly half the nutrients were supplied by commercial fertilizers, the other half by the cattle manure and in some instances by legumes (Domanico, 1985, p. 84, 109). Although the sources of nutrients varied across versions of the model, comparable quantities of nutrients were applied. For this reason, crop yields were assumed to be the same for all versions of the model.

Each of the eleven versions of the linear programming model was run initially with no constraint on soil erosion. Then soil erosion was constrained from its initial level down to one ton per acre by increments of one ton. Average soil erosion for the entire farm was limited in the models. Soil erosion on some fields of the farm could exceed the average constraint as long as the farm's total erosion was within the constraint. Information was generated on returns over

Table 1. Income Ranking of Six Versions of the Model at Alternative Levels of Soil Erosion ($).

Rank	10 Tons	9 T/A	8 T/A	7 T/A	6 T/A	5 T/A	4 T/A	3 T/A	2 T/A	1 T/A
1	NO−TILL 55,006	NO−TILL 55,006	NO−TILL 55,006	NO−TILL 55,006	NO−TILL 55,006	NO−TILL 55,006	NO−TILL 54,493	NO−TILL 53,301	NO−TILL+CC 51,580	NO−TILL+CC 45,128
2	CONV 53,219	CONV 53,157	CONV 52,904	CONV 52,650	CONV 52,212	ORG3 51,743	NO−TILL+CC 51,580	NO−TILL+CC 51,580	NO−TILL 46,002	NO−TILL 27,623
3	ORG3 51,743	ORG3 51,743	ORG3 51,743	ORG3 51,743	ORG3 51,743	NO−TILL+CC 51,580	ORG3+OS 50,151	ORG3+OS 46,149	ORG3+OS 20,940	
4	NO−TILL+CC 51,580	NO−TILL+CC 51,580	NO−TILL+CC 51,580	NO−TILL+CC 51,580	NO−TILL+CC 51,580	CONV 50,811	CONV+OS 49,879	CONV+OS 40,428	CONV+OS 16,859	
5	ORG3+OS 50,151	ORG3+OS 50,151	ORG3+OS 50,151	ORG3+OS 50,151	ORG3+OS 50,151	ORG3+OS 50,151	ORG3 45,423	ORG3 33,153		
6	CONV+OS 50,022	CONV+OS 50,022	CONV+OS 50,022	CONV+OS 50,022	CONV+OS 50,022	CONV+OS 50,022	CONV 41,341	CONV 29,914		

cash operating costs, area of each crop, and least-cost feed mixes for each version of the model at each level of soil loss (Domanico, 1985).

Findings

When the level of soil erosion is unconstrained in the organic versions of the model, the most profitable crop mix consists of corn silage, which is fed to cattle, and alfalfa hay which is both fed to cattle and sold off the farm. The addition of small grains to the crop mix reduces returns, especially when all four types of small grains must be produced. Returns for ORG, which produces all four small grains, are $3,100 less than for ORG1 which produces only the most profitable small grain, wheat. ORG3, which allows alfalfa to take the place of small grain, is more than $6,000 more profitable than ORG.

Given the prices assumed in this study, it is profitable to purchase rather than produce straw bedding. There is considerable monetary cost associated with any agronomic benefits that might be gained as a result of including small grains in the crop rotation. It is also much more profitable to sell crops for cash than through a beef finishing enterprise. The herd size of 213 head had to be forced into the model for all versions of the model. To see how profitability would be affected, ORG1 was modeled without beef, assuming that N, P, and K that would have been supplied by cattle manure were replaced with manure purchased at the price of the nutrients in commercial fertilizer. ORG1 with no beef cattle provides returns $5,682 higher than ORG1 with beef.

All versions of the model meet the successively lower constraints on soil erosion by transferring erosive crops such as corn silage to less erodible land, by reducing the intensity of the crop mix, and eventually by modifying the feed mix. Unless the model is forced to grow small grains and timothy/clover hay, the optimal feed mix is always corn silage and alfalfa hay. As soil erosion constraints become more stringent, timothy/clover hay is substituted for some of the corn silage and alfalfa. Timothy/clover hay is the least erosive crop but it has lower yields and nutritional value than alfalfa and corn silage; thus more land is needed to feed the livestock with timothy/clover hay than with corn silage and alfalfa. Since less land is available for cash crops, income declines significantly. In some versions, corn grain and purchased soybean meal are added to the diet under very tight soil erosion constraints. A feed mix other than corn silage and alfalfa is used only when soil erosion is tightly constrained, always with a major reduction in income.

Table 1 presents returns over cash operating costs for the six most profitable versions of the model, in order from highest to lowest profit, at each level of soil erosion. When soil erosion is ignored, NO-TILL is the most profitable option, providing returns of $55,000. The option with the next highest returns is CONV, at $53,200, followed by ORG3 producing returns of $51,700. The average soil erosion for these three options are 4.88, 9.69, and 4.72 tons per acre, respectively (Table 2). The versions that include overseeding produce lower returns than their counterparts without overseeding, since overseeding increases production costs for corn, and it is assumed yields are not affected. Overseeding significantly reduces the soil erosion for each option.

Soil erosion constraints are met by adjustments in the crop mix. As soil erosion is successively constrained to lower levels, systems with the highest unconstrained levels of soil erosion are the first to suffer a reduction in profitability. For example, since the unconstrained level of soil erosion for CONV is 9.69 tons per acre, every decrement of the soil erosion limit below that level causes a decline in income, whereas NO-TILL and ORG 3 suffer no decline until soil erosion is constrained to 4 tons per acre or less.

As the soil erosion constraint is reduced from 9.69 to 6 tons per acre, income for CONV gradually declines while returns for the other options remain unchanged. At the 5 ton per acre level, options that do include overseeding are still less profitable than the analogous versions that do not.

When soil erosion is constrained to 4 tons per acre, NO-TILL is still the most profitable option, followed by NO-TILL+CC, and ORG3+OS. Other versions of the model lose income to

Table 2. Income Foregone to Meet 3 Ton Per Acre Constraint on Soil Erosion

Version of Model	No Constraints on Erosion		3 Ton/Acre Constraint	Decrease in Income	
	Returns ($)	Soil Erosion (Tons per Acre)	Returns ($)	Dollars	Percent
ORG3	51,743	4.72	33,153	18,590	35.9
ORG3+OS	50,151	3.27	46,149	4,002	7.9
CONV	53,219	9.69	29,914	23,305	43.8
CONV+OS	50,022	5.03	40,428	9,594	19.2
NO-TILL	55,006	4.88	53,301	1,705	3.1
NO−TILL+CC	51,580	1.95	51,580	0	0

meet the 4 ton constraint. Both the organic and conventional options with overseeding now out-perform their counterparts without overseeding. ORG3+OS and NO-TILL-+CC are still unaffected by tightening the soil erosion constraint from 5 to 4 tons per acre.

All versions except for NO-TILL+CC are affected when the soil erosion constraint is dropped to 3 tons per acre. Income for NO-TILL is reduced by only about 3 percent. Again, the organic and conventional versions that include overseeding are not affected as severely by the constraint as versions without overseeding. Here we also see a widening spread between the organic and conventional options as soil erosion is restricted to 3 tons per acre.

At 2 tons per acre of soil erosion all versions without overseeding, with the exception of NO-TILL, yielded negative returns over cash operating costs. NO-TILL+CC is still unaffected by the constraint and becomes the most profitable option at $51,600 returns over cash operating cost. NO-TILL+CC and NO-TILL are the only options that can provide positive returns when soil erosion is limited to one ton per acre.

Table 2 presents the estimated opportunity cost, or profit foregone, to reach a 3 ton per acre limit on soil erosion for organic, conventional and no-till options. The 3 ton per acre limit was chosen for this comparison as a rather conservative "tolerable" level (Culik et al., 1983). In reaching the 3 ton limit, the versions that do not include overseeding (except for NO-TILL) sustain losses in income of 35 percent or more as compared with their respective returns without any erosion control. CONV suffers the largest decline, 43.8 percent. The versions with overseeding incur much smaller declines in income. Only a 3 percent decline in income is necessary for NO-TILL to reduce soil erosion to 3 tons per acre, and no income is foregone using NO-TILL+CC, because only 1.95 tons of soil erosion would occur with this option. Table 3 presents the implicit cost--that is, annual income foregone-- per ton of soil erosion prevented at different constraints for each version of the model. Again, the OS and CC versions of the models are shown to incur smaller losses of income in attaining successively more stringent

Table 3. Incremental Implicit Cost Per Ton of Soil Erosion Prevented (dollars per ton)[1]

Version of Model	Soil Erosion Constraint (Tons/Acre)									
	10	9	8	7	6	5	4	3	2	1
ORG3	0	0	0	0	0	0	29.86	41.74	*	*
ORG3+OS	0	0	0	0	0	0	0	13.61	85.75	*
CONV	0	.31	.86	.86	1.49	4.77	32.21	38.87	*	*
CONV+OS	0	0	0	0	0	.57	.47	32.15	80.17	*
NO−TILL	0	0	0	0	0	0	1.98	4.05	24.83	62.51
NO−TILL+CC	0	0	0	0	0	0	0	0	0	23.10

* Not applicable because production is unprofitable at these levels of soil erosion.
[1] Decline in annual net cash income associated with attaining a one ton per acre reduction in the entire farm's average soil erosion, divided by the tons of soil erosion prevented.

levels of erosion control, and the conventional versions generally incur a more severe income loss than the organic or no-till options.

Discussion

Interpretation of net returns

The profitability of various options in this study is computed as net returns over cash operating cost. Use of this measure avoids a number of assumptions regarding on-farm labor supply, farm debt, tax rates, land ownership costs, and other factors that can vary tremendously from one location and situation to another. In translating net return over cash operating costs into the family's disposable (spendable) income, it is necessary to subtract other costs, such as depreciation, interest, insurance, taxes and other overhead items, and add income from off-farm sources.

Machine ownership costs and labor requirements

Machine ownership costs and labor requirements are not taken into account in calculating net returns in this study. Based on other studies, inferences can be made about how machine ownership costs and labor requirements would compare across the versions of the model. It is reasonable to assume that the labor requirements would be higher for the organic versions of the model than for the conventional versions. An obvious reason for this is that cultivation is used for weed control in organic versions instead of herbicides. Klepper et al. (1977) found that labor requirements for organic farms were 11 percent higher than for conventional farms: 19.8 hours per $1,000 of crop output as compared to 17.8 hours. Labor requirements for the no-till versions would be less than for the conventional versions because of fewer field operations (Jolly et al., 1983).

Machine ownership costs for the organic and conventional versions of the model would be similar. Klepper et al. (1977) found that "the organic and conventional groups differed little in the type and size of machinery and equipment they owned and used in field operations." There is some evidence that machinery costs for the no-till versions might be somewhat lower than for the conventional and organic versions, especially if no-till equipment is owned instead of, rather than addition to, conventional equipment (Hinman et al., 1983; Jolly et al., 1983; Phillips, 1978). In a study of a farm similar to the Kutztown farm, Crowder estimated annual fixed machinery costs for no-till machinery would be 96 percent of the comparable cost for conventional machinery, versus 103 percent for the combination of no-till and conventional (Crowder, 1984, p. 50).

Overseeding. In general, overseeding improves the profitability of both the organic and conventional versions when soil erosion is constrained to four tons per acre or less. Because of difficulty in obtaining accurate estimates of nitrogen fixation, this study gave no credit for the nitrogen fixed by the legumes overseeded into corn. For this reason, the profitability of versions that include overseeding may be somewhat understated. According to Martin and Touchton (1983), "Annual establishment and maintenance costs associated with the production of legume cover crops are generally offset or surpassed by the value of the nitrogen they produce." If this study had assumed that

the extra cost of establishing legumes was offset by the value of the nitrogen they fixed, the results would have shown versions with and without overseeding to be equally profitable when high levels of erosion are tolerated, and versions with overseeding to be even more profitable at low levels of soil erosion. Conversely, if the value of the nitrogen fixed by the overseeded legume is in fact negligible, then the cost of overseeding could be reduced by the use of a less expensive non-legume, a cereal or grass crop such as rye. Since cereals and grasses have a more fibrous root system and produce more dry matter than legumes, overseeding with these crops may provide equal or better erosion control than overseeding with a legume.

Advantages and disadvantages of no-till. Given the assumptions about soil erosion and costs of production in this study, no-till has an advantage over other options both in producing income and conserving soil. The lower costs of production and the soil conserving capability of NO-TILL and NO-TILL+CC make them the most profitable options at all levels of soil erosion. The combination of no-till and a cover crop provides such effective erosion control that a $45,128 net return over cash operating cost can be maintained with this option even when soil loss is constrained to one ton per acre.

Although this study assumes lower variable costs of production under no-till than conventional production (based on the Penn State Agronomy Guide, 1985-86), other studies have found that additional pesticide costs exceed the value of the fuel saved, making variable costs for no-till equal to or slightly higher than conventional costs (Epplin et al., 1983). If no-till costs were assumed to be equal to or greater than conventional costs in this study, the profitability of the no-till options would decrease at all levels of soil erosion. However, since their ability to conserve soil would remain unchanged, the no-till versions would still be able to maintain profitability at low levels of soil erosion. Even if no-till costs were assumed to be substantially higher, at low levels of soil erosion the no-till versions would remain the most profitable. Although the costs of production for no-till may be understated in this study, there is no reason to believe that the adoption of NO-TILL under favorable soil conditions would be detrimental to farm income in the area where this study was conducted. There is much evidence that no-till is an economical practice for conserving soil where soil properties are favorable (Crosson and Stout, 1983; Forster et al., 1985; Pope et al., 1983).

There are other advantages to no-till production besides profitability and erosion control (Phillips, 1978). No-till production of corn and soybeans requires only 50 to 75 percent of the energy required for conventional production. Soil compaction is also decreased because of fewer trips over the field and moisture retention is improved. Approximately 20 percent more soil moisture is available for crops under no-till production than conventional, which may reduce plant stress during short drought periods.

Despite its advantages, No-till also entails problems. One problem is that it can only be applied where the soil is suitable, which excludes heavy clay or poorly drained soils. Other problems may include increased pest populations, increased susceptibility to plant disease, herbicide carryover, weed resistance, and shifts in weed species (Hinkle, 1983). There is also growing concern about human health risks associated with pesticides. The long-term effects of increased chemical use to combat the problems associated with no-till production are not fully understood. Although no-till helps to reduce pollution from sedimentation, it may increase the concentration of chemicals dissolved in surface drainage and runoff (Baker and Laflen, 1983).

If these problems are overlooked, and only profitability and soil conservation are taken into account, then the no-till versions are superior to the other options considered in this study when soil and weather conditions are favorable. Even without constraints on soil erosion, no-till is the most profitable option by more than $1,700 under the price and yield assumptions used in this study. As soil erosion is constrained, the advantages of the no-till options increase. Under no-till, soil erosion can be reduced to 3 tons per acre with only a 3 percent decline in income. Using no-till with a cover crop it is possible to reduce soil erosion to as low as one ton per care and still provide returns of over $45,000.

Conventional versus organic options. The conventional version of the model without overseeding is the second most profitable option when no limit is placed on the amount of soil erosion. The average soil erosion for the entire farm would be nearly 10 tons per acre per year. The short-term income advantage of the conventional model over the most profitable organic version is considerable when levels of soil erosion are ignored, but its advantage diminishes as soil erosion is limited. Returns for the conventional version are severely limited by constraints on soil erosion below 5 tons per acre. The profit advantage of the conventional version at high levels of soil erosion is due to its intensive rotation. As soil erosion is constrained, it is forced to reduce the intensity of the rotation, and its relative profitability is diminished. When the conventional version is forced to have a low-intensity rotation comparable to an organic rotation, it is less profitable than the organic version.

The addition of overseeding greatly reduces the soil erosion associated with conventional production. Below 4 tons per acre of soil loss, the conventional version with overseeding becomes more profitable than the conventional version alone.

As long as soil erosion is ignored, the best organic version, ORG3, is approximately $1,500 (2.8 percent) less profitable than the conventional version. Since the organic version is less severely affected by the soil erosion constraints, the difference in profitability between ORG3 and the conventional version decreases as soil erosion is more tightly limited. Below 5 tons per acre, the organic versions earn higher incomes than the conventional versions. The short-term profitability of the conventional systems is superior to that of the organic systems only when high levels of soil erosion are permitted.

As with the conventional versions when soil erosion is contrained to 4 tons per acre or less, the organic version with overseeding becomes more profitable than the corresponding version without overseeding. Overseeding allows a more profitable rotation to be maintained at low levels of soil erosion.

Summary of findings. When conventional or organic cropping practices are used, a less intensive crop rotation (with fewer acres of row crops) must be used to achieve lower levels of soil erosion. This substitution of forages for high-value row crops is the primary cause for reductions in income associated with erosion control. Thus, management practices that can control erosion with the least reduction in the intensity of rotation, such as overseeding and no-till, are the most profitable options when soil erosion is constrained to levels less than 5 tons per acre. These results are in agreement with other studies. The cost of controlling soil erosion in terms of foregone profits increases the more tightly soil erosion is contained. Strictly limiting soil erosion becomes especially costly on farms with livestock when it becomes necessary to alter the feed mix to include lower nutrient-yielding crops.

Regarding the feasibility of organic farming, this study found that under an organic system, the lower value of crop output due to a less intensive rotation is partially offset by lower production costs. This makes organic production slightly less profitable than conventional production when levels of soil erosion are ignored. However, this study goes a step beyond previous research by comparing organic and conventional systems at various levels of soil erosion. When soil erosion is constrained to a whole-farm average of less than 5 tons per acre, the organic system becomes more profitable than the conventional system. For both organic and conventional systems, it was found that overseeding of legumes into corn during the last cultivation makes a more intensive (and more profitable) rotation possible at low levels of soil erosion.

Limitations. The results of this study are based on data from a single Pennsylvania crop and livestock farm. The extent to which these results can be generalized is limited in several ways.

The results from the organic versions of the model pertain only to farms where a transition to an organic system is complete. This study is based on a farm where an organic system has been used for many years and yields are comparable to state and county averages. During the first several years of a transition to an organic system, crop yields may decline, as they did on the Kutztown farm (Wegrzyn, 1984). It may not be reasonable to apply the results of this study to farms in the early stages of a transition to organic production. The organic versions of the model also depend on manure for supplying nutrients to crops. For this reason, the results of the study can only be applied to mixed crop and livestock farms, or crop farms that have access to off-farm sources of manure.

For the results from the no-till versions to be applicable, soil and climatic conditions would have to be favorable to no-till production. This study assumed no-till yields would be the same as conventional yields, and costs of production would be lower under no-till than conventional systems.

Except for its minimal use of chemicals, the actual farm that was modeled is similar to many Pennsylvania farms. The possibility of implementing the management options included in this study exists on many Pennsylvania farms. However, the impact on soil erosion and income of implementing these options on specific farms would depend on the soil, management, and other resources found on those farms, as well as the prices of commodities sold and inputs purchased.

Suggestions. The ecological impact of each management option in the study could be more thoroughly evaluated if chemical run-off and percolation, as well as soil erosion, were measured. A model like CREAMS that could measure run-off, erosion, and transport of chemicals would provide much more information than the USLE alone. CREAMS is an acronym for *A Field Scale Model for Chemicals, Runoff and Erosion from Agricultural Management Systems* (Knisel and Nicks, 1980). The CREAMS model is a physically-based simulation model for estimating runoff, erosion and transport of chemicals (nitrogen, phosphorus and pesticides) in solution and attached to sediment. The model is used to evaluate the effects of alternative cropping systems on the yields of sediment and chemical pollutants from field-sized areas (Crowder et al., 1984). If sufficient data were available to use the CREAMS model, chemical losses as well as soil erosion could be constrained and the profitability of the management options could be compared under these more rigorous ecological constraints.

Average soil erosion for the entire farm is constrained in this study. Soil erosion on some areas of the farm were allowed to exceed the constraint as long as the 294-acre farm average was within the constraint. Even if erosion is limited for the entire farm, allowing excessive erosion on certain fields can have a harmful effect on water quality and the long-term productivity of erosive soils. Constraining soil erosion for each acre on the farm would eliminate this problem. It would also significantly reduce the income earned on the most erosive soils, except where overseeding or no-till practices are used.

Another useful addition to the study would be to incorporate accurate estimates of the value of the nitrogen fixed by legumes in the systems which use overseeding. The price of nitrogen fertilizer could be varied and the relative profitability of overseeded systems could be examined at the various price levels. It would also be interesting to vary the prices of other inputs and the selling prices for crops. In this study, the relative prices of alfalfa and corn allow the organic versions which depend on alfalfa sales to compete favorably with the chemical-intensive versions which rely on corn. A thorough comparison of alternative commodity price scenarios, as well as actual fixed costs and labor requirements for the different options, would give better insight into the relative profitability of the options.

Finally, studies like that that focus on an individual farm have several inherent limitations. Obviously, the results may not apply to other locations. Many replications are needed. The methodology employed in this study is rather time-consuming and expensive. Furthermore, studies of this kind presume that only a miniscule fraction of the total number of farms changes to organic farming. If large numbers of farms were to make the transition, many of the parameters assumed in this study would undoubtedly change--shortages of manure could elevate the price of this input and changes in aggregate production of hay and other crops would lead to changes in market prices (Langley et al., 1982). Consequently, this study must be interpreted realistically as a single-farm

model whose direct macroeconomic implications are as yet unexplored.

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INSTITUTE NEWS

Groundwater pollution is 1987 symposium topic

The connection between agricultural production practices and groundwater contamination will be explored at the fourth annual scientific symposium presented by the Institute for Alternative Agriculture. The one-day event will be held next March 3 in Washington.

Garth Youngberg, IAA's executive director, said the symposium will document the nature and extent of the nation's growing groundwater pollution problem. "It is now widely agreed that chemical pollution of this water resource has been accelerated by modern farming practices," he said. "The massive shift in recent years away from soil-conserving crop rotations to chemical-intensive monocultural cash grain systems has contributed significantly to this problem."

The symposium, Youngberg emphasized, will present a full range of constructive alternatives for solving the problem within the context and needs of modern production agriculture.

"Although the regulation of harmful agricultural chemicals will be considered, this symposium will go beyond the usual call for more effective regulation," he said.

Schaller and Ebenreck join editorial board

Neill Schaller of USDA's Economic Research Service and Sara Ebenreck of the American Land Resource Association have accepted invitations to join the editorial board of the *American Journal of Alternative Agriculture*. Editor Garth Youngberg said their acceptances increase the number of editorial board members to 29.

Schaller, an economist, is assistant director of the Natural Resource Economics Division at ERS. Ebenreck, a writer on land use policy and values, is executive editor of *American Land Forum*, ALRA's quarterly journal.

Urban consumers' attitudes towards locally grown produce

William Lockeretz

Abstract. *In areas where farmland is under heavy development pressure but where farms are too small to compete in major marketing channels with larger farms in other regions, producers must use channels that capitalize on their proximity to consumers. This advantage is greatest for fresh fruits and vegetables, provided farmers understand their urban customers' purchasing preferences. This study interviewed more than 600 customers at farmers' markets and supermarkets in six urban and suburban communities in eastern Massachusetts and at agricultural fairs. Respondents were asked about their reasons for purchasing fruits and vegetables at various sites, about their preferences, if any, for produce grown locally, and about changes that might cause them to purchase more local produce. The results suggest that for local origin to be taken into account by consumers, the produce should be sold in a locally oriented environment, e.g., a farmers' market. Although the particular supermarkets in this study featured locally grown produce in their advertising, this seems to have had little effect on consumers' buying. Conversely, consumers' highly favorable opinion of farmers' markets involved several factors besides the localness of the produce in a purely geographic sense. These included the pleasant environment, the (presumed) short time since the produce was picked, and the opportunity to purchase directly from the producer in a face-to-face transaction.*

Direct marketing as a component of strategies to sustain farming near cities

In the past few decades there has been considerable interest in ways of preventing, or at least slowing, the conversion of farmland to nonfarming purposes on the fringes of metropolitan areas. The methods to achieve this may be classified as negative or positive, although perhaps "preventive" vs. "constructive" might be a better description. By negative, I mean measures intended to reduce the forces that induce farmers to leave farming (Coughlin, 1979). These include such well known techniques as use value assessment of farmland to reduce the tax burden on farmers (Collins, 1979), purchase of development rights to insulate farmland from speculative pressure (Lapping, 1980), and right to farm laws that protect farmers from complaints of neighbors about noise, dust and odors (Lapping et al., 1983).

Most of the literature on farmland preservation and farm-city interactions focuses on such techniques. These techniques may remove certain obstacles to farming near cities, but they do not guarantee that farms near cities will survive. Thus a complete program for preserving farming near cities should include constructive measures that enhance the attractiveness of farming, whether economically or in other ways. This means that proximity to a city should be turned into an advantage, not merely that its disadvantages should be minimized.

A key element in such a strategy is to capitalize on the short distance from producer to consumer in the case of fresh fruits and vegetables. Farmers in heavily urbanized regions such as the Northeast would be at a distinct disadvantage in trying to compete in large-scale marketing channels against larger producers in other areas where production is physically and economically more efficient. But they have a definite advantage in marketing their produce directly to local consumers, assuming they understand their urban customers' purchasing preferences. People who are strongly involved in direct marketing or in other ways of promoting local agriculture often take for granted, without empirical confirmation, that the general public necessarily shares their high opinion of locally grown produce.

Several recent studies have investigated the demographic characteristics and buying habits of customers buying directly from farmers in farmers' markets and roadside stands (Adrian, 1982; Pelsue, 1984; Estes, 1985). However, unlike the present study, they have not explicitly compared these customers to those using conventional channels, such as supermarkets. The study reported here makes this comparison to help farmers and agricultural officials understand actual and potential direct marketing customers better and thereby capitalize on an important advantage of farming near a metropolitan area.

Data collection

The primary data in this study were obtained by interviewing shoppers in six communities in eastern Massachusetts, including the two largest cities in New England (Boston and Worcester) and four towns and cities in the Boston metropolitan area. Economically, they ranged from a working class community with a substantial immigrant population to a very affluent community with a large professional/managerial population.

In each community, interviews were conducted at a farmers' market and at a supermarket. These farmers' markets are open only to Massachusetts growers, who may sell only products that they themselves have raised. The supermarkets were all part of a chain that particularly features Massachusetts grown

William Lockeretz is a research associate professor at the School of Nutrition, Tufts University, Medford, MA 02155.

produce and that heavily advertises that fact during the summer and fall when local produce is most available. Where there were several stores of this chain in a particular community, we chose the one closest to the farmers' market; distance between the farmers' market and the supermarket ranged from a few blocks to about two miles. Supermarket interviews were done during the same period (June to October, 1984) as the farmers' market interviews. All the farmers' markets are open only during the day on weekdays, typically for one or two days per week, three to five hours per day. At three locations our supermarket interviews were at comparable times. At two others, we interviewed respectively on a weekday night and Saturday morning; interviews at the sixth supermarket were on both a weekday afternoon and evening. A total of 264 shoppers were interviewed at the six farmers' markets (range: 24 to 54 per market); 283 were interviewed at the supermarkets (range: 34 to 59).

Additional interviews were held at two agricultural fairs in eastern Massachusetts (total of 115), mainly to extend the sample to include more respondents from less densely populated portions of the region, who are more likely to go to farmstands or U-Pick operations. Because the overall study involves three different kinds of sampling sites, an overall sample mean for a single variable by itself is not particularly meaningful. Either the subsamples are compared to each other with regard to an individual variable, or two different variables are compared for the same respondents (either within a particular subsample or for the overall sample).

The interviews were kept very brief, typically running 5 to 7 minutes, since the respondents were doing something else at the time (shopping or visiting the fair). The main topics covered were: places where the respondent customarily buys produce; the advantages and disadvantages of each; the advantages and disadvantages of locally grown produce; and some personal characteristics. All opinion questions were open ended, with the answers coded by the interviewer without the respondent seeing the possible choices.

Overall, 66% of those approached agreed to be interviewed. The response rate varied only slightly among different groups. When broken down by age, sex, race, or kind of interview site, the only case in which it fell below half was a rate of 47% for non-whites as compared to 68% for whites.

Table 1. Personal characteristics of customers at farmers' markets and at supermarkets in the same communities.

	Farmers' Market	Supermarket	Difference[a]
Not primary food shopper in household (%)			
Supermarket interviews in daytime	24	15	9 (P < .05)
" " Saturday or evening	21	18	3
Has job with regular hours (%)			
Supermarket interviews in daytime	59	44	15
" " Saturday or evening	53	70	−17 (P < .10)
Education[b] (0 = less than h.s. grad.; 5 = some college: 10 = postgraduate or prof. degree)	5.4	4.3	1.0 (P < .10)
Occupational status[b] (0 = unskilled or manual laborer; 5 = skilled laborer: 10 = professional/managerial	6.3	5.8	0.6
Race (% non-white)	6	5	1
Sex (% female)	75	76	−1
Age	45	47	−1
Marital status (% married)	50	48	2
Raised on farm or parents raised on farm (%)	30	25	5
Raise some of their own food (%)	26	26	0

[1] Unweighted mean over all communities of the difference between the mean for the farmers' market and for the supermarket in the same community. Significance computed by 2-sided t-test applied to these within-community differences. Whole sample data are from 6 pairs of markets, except education (4 pairs). Where there is a breakdown by time of supermarket interview, farmers' market data are for the same communities as the supermarket data (4 pairs with supermarket interviews during the day on a weekday; 3 pairs with supermarket interviews on Saturday or evening). Figure shown may not correspond to difference of the other two columns because of rounding.
[b] Mean of respondent and spouse, where applicable.

Results

Characteristics of farmers' market and supermarket customers

The main difference between customers at the two kinds of markets, as shown in Table 1, concerns employment. Because the farmers' markets are only open during weekdays (although sometimes through dinner time) we divided the sample according to when the supermarket interview occurred. Compared to shoppers at supermarkets during the day on weekdays in the same communities, farmers' market customers are more likely to have a job with regular hours (59% compared to 44%), but less likely than customers shopping at supermarkets at night or on Saturday (53% compared to 70%). (The proportion of farmers' market customers with jobs is different in these two comparisons because each figure includes only those communities where supermarket interviews were held at the indicated time.) The first result suggests that working people make a particular point of getting to the farmers' market despite their jobs, for example during lunch break or on the way home. On the other hand, this is not always possible, so that fewer farmers' market customers have jobs than do people shopping at a time when having a job is no hindrance. (The category "have a regular job" includes people on their day off or vacation, which probably explains why the figure for daytime supermarket shoppers was as high as 44%.)

Farmers' market customers include more people who are not the main food shopper in their households when compared to daytime supermarket customers; the difference was small compared to Saturday or evening supermarket customers. This suggests that people specifically seek out the farmers' market, and hence may be different members of the household from those

oing the main shopping. This is consistent with the previous finding in that ny working person who goes to a farmrs' market (necessarily on a workday) likely to be doing that shopping only, ot general food shopping, which can be ft to a more convenient time.

Other differences in the kinds of peole shopping at each kind of market were inor. (For all remaining characteristcs, separating the sample according to hen the supermarket interview was one had a negligible effect, so that the esults are shown only for the total samle.) Farmers' markets had somewhat nore customers from a farm backround, although they were no more ikely to raise any of their own food now. Farmers' market customers tend to be lightly better educated. Differences in he age, occupational status, marital staus, sex, and race of the two groups were egligible.

Preference for locally grown produce and reasons for buying produce at different places

Respondents were given three opportunities to indicate whether they preferred local produce. Before the subject of locally grown produce was ever brought up, they were asked to name all the places where they shop for produce. For each place we then asked "Why do you buy your produce there?" A respondent might say "because they have locally grown produce" or "because I want to give business to local farmers." Later, we asked "When you choose the produce you buy, what do you take into account?" If they did not mention origin of the produce in either question, we then asked "When you choose produce, does it matter to you where the produce was grown?" Respondents were considered to have a strong preference if they mentioned locally grown for either of the first two questions, a moderate preference if it was mentioned after being asked explicitly, and no preference if it was not mentioned even after the third question. (Throughout, we regard the response "Massachusetts grown" as equivalent to "locally grown," although strictly speaking they are different: some out-of-state farms are closer to the interview sites than the main produce growing area of the state, some 100 miles west of Boston. "Locally grown" has no precise definition, and the respondents seemed to be using the terms without making a careful distinction.)

Table 2. Respondents' preferences for Massachusetts grown produce, by where interviewed and where they shop for produce in season.

	By where interviewed		
	Farmers' Market (n=263)	Supermarket (n=278)	Agric. Fair (n=115)
No preference	47%	73%	49%
When asked	36	20	33
Without being asked	17	7	18
TOTAL	100%	100%	100%

	By where they buy produce in season		
	Only in Locally Oriented Places[a] (n=109)	Both Kinds (n=245)	Only in Non-Locally Oriented Places[a] (n=302)
No preference	34%	49%	75%
When asked	38	35	20
Without being asked	28	16	5
Buy in at least one place because it has locally grown produce[b]	19	10	1
TOTAL	100%	100%	100%

[a] Locally oriented places are farmers' markets, roadside stands, and pick-your-own. Non-locally oriented are supermarkets, neighborhood fruit and vegetable stores, grocery stores, food cooperatives, convenience stores, and natural/organic food stores.

[b] One of the two ways in which a respondent would be classified as expressing a preference for locally grown produce without being asked.

The relation of preference for local produce to shopping site is shown in Table 2. Not surprisingly, the preference is much higher among farmers' market than supermarket customers. However, the preference is weak among both groups. Even at the farmers' markets, where local produce is the whole purpose of the market, almost half of the customers indicated no preference and another three-eighths expressed a preference only when asked explicitly. Among supermarket customers, almost three-quarters had no particular preference, and only 7% cared about it enough to mention it without being asked explicitly, even though the supermarkets in this study heavily promoted local produce. The preferences of the agricultural fair respondents were similar to those of the farmers' market customers.

Similar results were obtained when the respondents were classified by all the places they shop for produce in season, rather than where they were interviewed. Of course, those who shop entirely or at least partly in locally oriented markets (farmers' market, roadside stand, or U-Pick) have a greater preference for Massachusetts grown produce. However, even among those who only shop in such places, barely over one-fourth (28%) had a strong enough preference to state it before being asked, and one-third had no preference even after being asked a question that almost invited the respondent to mention locally grown. Only 19% of those who shop only at locally oriented places mentioned availability of locally grown produce as a reason for choosing where they shop.

These results suggest that although preference for local produce is certainly a factor in inducing customers to come to farmers' markets and other locally oriented outlets, it is only a weak factor since many of the customers do not share this preference. This point is further reinforced by the reasons given for shopping at the various kinds of markets (Table 3).

The first two columns give the reasons the respondents shop at any kind of market in the locally oriented or non-locally oriented categories respectively. The next three give the reasons that farmers' market and supermarket respondents buy produce at those particular sites, and also, for farmers' market customers who also buy produce at supermarkets, their reasons for doing so. An important point regarding the last column is that

Table 3. Reasons given for buying produce at different kinds of places[a].

	All Respondents		Interviewed at Farmers' Market		Interviewed at Supermarket
	Any Locally Oriented Place (n=334)	Any Non-Locally Oriented Place (n=542)	Reasons for Farmers' Market (n=193)	Reasons for Supermarket (n=111)	Reasons for Supermarket (n=247)
Freshness/ Quality/Looks	84%	22%	84%	7%	11%
Pleasant/like to deal with individuals	17	5	20	1	4
Want to support local farmers	14	0	16	0	0
Previous two reasons combined	26	5	30	1	4
They have local produce	13	1	12	0	1
Support local or they have local produce	20	2	23	0	1
Good prices	15	22	17	18	22
Convenience	7	65	10	72	8
Good selection	8	15	7	10	13

[a] Column totals are more than 100% because respondents could give as many reasons as they wished. Farmers' market responses exclude people who had only recently begun shopping there, or who were just looking around. Farmers' market shoppers' reasons for shopping at supermarket are given only for respondents who also gave reasons for shopping at farmers' market.

these reasons were given while the respondents were shopping in a supermarket that specifically publicizes local produce.

The overwhelming reason for using locally oriented markets is the perceived freshness and quality of the produce: 84% of the respondents who ever shop at a locally oriented place mentioned this in connection with at least one such place (Table 3, col. 1). (This proportion applied both to farmers' market respondents regarding farmers' markets [col. 3] and to all respondents regarding any locally oriented market [col. 1].) Undoubtedly, even if they did not mention it explicitly, local origin is a reason that some respondents consider the produce at locally-oriented markets to be fresher and of better quality. Nevertheless, "local" and "fresh" are not the same, as will be discussed later. Therefore it is interesting that only 13% of these same respondents specifically mentioned availability of local produce as a reason they shop at any market in that category (Table 3, col. 1). Also, as was already seen (Table 2, bottom row), this increases only to 19% among respondents who do all their in-season produce shopping at locally oriented places. (Table 3 does not break down the two left columns further, but in general there are only slight differences between respondents who only shop in the indicated category of market and those who also shop in the other category.) If the reason "to support local farmers" is included with "because they have Massachusetts grown produce," then 20% of all respondents who shop at locally oriented places do so for at least one reason related to the local origin of the produce (Table 2, col. 1). This is comparable to the number mentioning price (15%), or that it is pleasant/or that they like dealing with individuals (17%).

In contrast, for customers shopping for produce at non-locally oriented places, convenience is by far the most important reason behind the choice. This is true for all respondents and all such markets. There is little difference between shoppers interviewed at supermarkets and farmers' market customers who also shop for produce at supermarkets (cols. 5 and 4 respectively), o between respondents who always or onl sometimes buy produce at non-locall oriented places (not shown). As men tioned earlier, farmers' markets hav very limited hours and are never ope other then during normal workin hours. Supermarkets, of course, are ope much longer and are in more location Moreover, supermarket customers ca buy produce while doing their other gro cery shopping. Convenience was th only clear attraction of supermarkets Even though the particular supermar kets in this study feature local produce only 1% of the supermarket respondent gave this as a reason for buying produc there. Finally, price was a moderatel important factor at both kinds of mar kets.

Perceived advantages and disadvantages of local produce

Farmers' market and supermarke customers did not differ appreciably i what they considered the most impo

Table 4. Reported advantages and disadvantages of Massachusetts grown produce, by interview site.

	Farmers' Market	Supermarket
Advantages		
Freshness/quality	64%	45%
Support local farmers	42	36
Price	3	8
ANY ADVANTAGES	82	68
Disadvantages		
Price	10%	3%
Short season	8	6
Limited selection	6	2
ANY DISADVANTAGES (includes minor ones not listed above)	28	13

tant advantages of local produce (Table 4). Both considered it fresher and both liked the idea of supporting local farmers. Price was not a factor either way. Neither group cited any major disadvantages for local produce. Interestingly, farmers' market customers were more likely to mention some disadvantage, probably because they have had more experience with local produce and care more about it.

Although supermarket customers appear to have a high opinion of local produce, this does not affect their purchasing decisions, as shown by the unimportance of local produce in deciding to shop at a particular supermarket. It must be remembered that the question tallied in Table 4 was explicitly about local produce, whereas the subject had not yet been raised when the previous questions were asked. The preference of supermarket customers for local produce apparently is not in the front of their minds when making shopping decisions, although at least they do not have a negative opinion that would prevent them from buying more local produce under the right circumstances.

Changes leading to more purchasing of local produce

What these circumstances might be is suggested by the data in Table 5. Farmers' market customers mainly want more places to buy local produce, consistent with the earlier finding that the main reason they sometimes buy produce in supermarkets is convenience.

In contrast, supermarket customers' answers to the same question seem to refer to buying more local produce at the place where they already buy produce (i.e., the supermarket), since they more often mention that it should be better labelled than that it should be available in more places. On the other hand, those supermarket customers who already have some interest in local produce (40% of the total) are more like farmers' market customers in that "buying more local produce" implies "buying it at more places" (col. 3). These customers are prime candidates to become farmers' market customers if they aren't already, or to increase the amount of produce they buy there. For all groups, the main change leading to more purchases of local produce is related to greater availability, whether at a supermarket or elsewhere. None of the groups indicated they were being held back by price or quality.

Relation to other studies

Freshness/quality was the leading reason for customers' liking farmers' markets in several other studies. However, some of these (Adrian, 1982, in Alabama, and Estes, 1985, in North Carolina) identified price as another particularly important reason, whereas Pelsue (1984), as here, found that in Vermont price is only one of several factors of about equal importance, all of which trail far behind freshness. Estes (1985), like the present study, found that desire to support local producers was of minor significance. In contrast, Pelsue (1984) reported that an overwhelming majority of farmers' market customers have a "strong preference" for locally grown produce. However, he did not report how this was determined; in the present study a preference was considered "strong" only if it was expressed before the respondent was asked explicitly about it.

Discussion

This study suggests that although urban customers have a predisposition for locally grown produce, this predisposition does not get converted to action unless an appropriate site is provided, such as a farmers' market. As a concept in its own right, preference for local produce is not the determining factor in consumers' buying habits.

It might be argued that the many respondents who said they shop at locally oriented places because of freshness and quality really had local origin in mind. However, buying produce because it is fresh is not the same as buying it because it is local: many respondents commented that even when a supermarket offers lo-

Table 5. Frequency with which respondents said they would buy more Massachusetts produce if the indicated change were made.

	Farmers' Market Respondents	Supermarket Respondents[a]		
		All	Some interest in local produce	No interest in local produce
Related to availability				
More places	31%	12%	21%	6%
Longer season	13	5	8	3
Better labelled	12	19	20	19
Longer hours	9	0	1	0
More publicity	3	5	4	6
Related to the products				
Cheaper	7%	10%	13%	9%
Better quality	3	4	5	4
More kinds	9	6	7	5
ANY CHANGES	64	44	54	38

[a] "Some interest in local produce" means customers who also buy produce in a locally oriented place, such as a farmers' market, or who expressed a preference for local produce (40% of all supermarket respondents). "No interest" refers to the other 60%.

cal produce, it often is not fresh by the time they buy it. Moreover, even though the supermarkets where we interviewed our respondents all publicize their locally grown produce heavily, apparently this was not a factor in the decisions of their customers to buy produce there. Conversely, what appeals to farmers' market customers is not simply that the produce was local, but also that it came to them directly and rapidly. Moreover, it was sold by the producer, with whom they are dealing directly, and the place in which it is sold is more pleasant than a supermarket.

Many states try to promote locally grown produce through slogans such as "Massachusetts grown . . . and fresher." Such slogans are used equally for supermarkets, roadside stands, or farmers' markets. A campaign that focuses entirely on where the produce was raised passes over an important part of the appeal of local produce. Our data, along with additional comments offered informally by our respondents, suggest that buying in a farmers' market has many attractions that a supermarket cannot hope to match, regardless of how much local produce it offers and how heavily it publicizes it.

Consumers believe--probably correctly--that once it is picked, produce arrives at a farmers' market sooner than at a supermarket. Moreover, although both groups of consumers like the idea of giving their business to the local producers, they really are giving them much more business at a farmers' market, where the farmer is not just a producer but also a vendor who receives the entire retail price. Also, at a farmers' market they deal with a farmer face to face. Besides adding a welcome human touch, this turns the abstract idea of "support your local farmer" into a tangible reality. Farmers' market customers hand their money to a living, breathing farmer. This has much more meaning than imagining a portion of the money eventually finding its way back through a complicated marketing chain to a nameless farmer, even if that farmer happens to be from the same state.

Finally, farmers' markets are a pleasant way to shop. They have a festive and neighborly atmosphere and offer an opportunity to get some fresh air while shopping. Also, the customer can get to know particular producer/vendors by name and learn who can be relied on for good quality and fair prices. These attractions apply just as well to products for which freshness is not particularly relevant, such as root crops. In contrast, a slogan emphasizing freshness and local origin in the abstract--separate from how the produce is sold--is not relevant to such products.

The only drawback to the farmers' markets described here was inconvenience compared to supermarkets. More locations, longer hours, and more days per week (both on weekends and weekdays) are obvious ways of addressing this problem. Another could be to permit vendors--either the current farmer/vendors or new merchants--to sell other products, such as types of produce not raised locally (or out of season locally), or baked goods, cheeses, and other suitable foodstuffs. This is done in some farmers' markets around the country. The point is to make it more worthwhile for the customer to make the extra trip to an additional shopping location.

This study suggests that steps such as these to enhance the convenience of farmers' markets would greatly expand the sales of local produce, which now is limited not by customer demand but by availability. Current farmers' market customers are highly satisfied, and simply need more buying opportunities. Customers at supermarkets at least potentially are also farmers' market customers. Demographically, the two groups differ little. Unlike some other kinds of specialized food outlets, farmers' markets are not elitist institutions that appeal mainly to a particular segment of the community. Instead, their customers are drawn from the population at large in whatever community the market happens to be, and successful markets can be found in a great variety of communities.

Agricultural officials interested in bolstering the economic situation of produce growers near urban areas would do well to go beyond publicizing where the produce was raised. Instead, efforts should be given to establishing marketing outlets that are locally oriented as outlets, in contrast to promoting conventional outlets that happen to get their produce from local sources. Buying local produce, and supporting local producers, applies to every step in the market ing chain: where the produce is raised how it gets from farm to market, an where and by whom it is sold. Farmers markets embody this totally local ori entation, which undoubtedly explain their considerable customer appeal.

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Fungal associations on field-weathered plants and their role in residue decomposition

Marion E. Simpson, Paul B. Marsh, and Lawrence J. Sikora

Abstract. *Basic microbiological information is presented which is relevant to an understanding of the decomposition of crop residues in conservation and conventional tillage practices. Little has been known about the role in crop residue decomposition of microbial populations that grow on dead leaves and stems of crop plants standing in the field after maturation. Even the identity of such organisms has not been thoroughly defined. Dead leaves and stems were collected from corn and from other field crop, garden, and native plants standing during weathering after maturation in fields at Beltsville, Md., and at seven other U.S. locations in the fall of 1984 and the spring of 1985. Certain "field fungi" from the genera Alternaria, Cladosporium, Fusarium, and Helminthosporium (Bipolaris) occurred as a common population growing on samples from most locations in spite of major differences in temperature and precipitation during the weathering. All fungi observed are known from the literature to be able to decompose native cellulose in pure culture. Some can grow on plant waxes. They grow poorly, if at all, in the absence of oxygen. All grow best in the presence of free water; none are true xerophytes, although some can resist wetting-drying cycles. They are mesophiles and exhibit most rapid growth at about 25-28 C. Some can survive over winter in plant tissues in cold climates. Probable relevance of these characteristics to residue decomposition in field situations is discussed.*

Maintenance of soil properties favorable to plant growth is widely understood to be related in part to the proper management of crop residues. However, further basic information is needed to improve our understanding of the microbial decomposition of plant residues that remain at or near the soil surface, this particularly in view of the current trend toward conservation tillage. Conservation tillage is defined as a non-inversion system that employs disk or chisel implements and leaves a substantial amount of plant residue at the soil surface for control of wind and water erosion (Ritchie and Follett, 1983). While many farmers have shifted to some version of conservation tillage, the 1980 USDA report on organic farming cited especially widespread use of conservation tillage among organic farmers (USDA, 1980). Most of these farmers had long since abandoned use of the moldboard plow, which inverts the plow layer and effectively buries crop residues while leaving bare erodible soil exposed to the elements.

In a review of factors affecting the decomposition of crop residues by microorganisms, Parr and Papendick (1978) referred to microorganisms that grow on above-ground parts of a crop plant prior to placement of a residue from it into or onto the surface of a soil as "indigenous" organisms. They stated that "Little is known about the role of the indigenous microflora in decomposition of mature crop residues applied to soils" and emphasized the need to "investigate the role of the indigenous micro-flora in decomposition of residues." This need can be seen in more specific terms in a paper by Parr and Reuszer (1959). These investigators found the rate of decomposition of wheat straw mixed with soils to be much greater than that of straw applied in a band or layer, but only during the first week of incubation. After a long period, cumulative decomposition was much greater for the straw in the banded or layered treatment. With respect to the response in the banded treatment, Parr and Papendick (1978) stated: "Whether the indigenous microflora of the straw was responsible for this result is not known." An important question with respect to conservation tillage is: "How much do the indigenous microorganisms contribute to the decomposition of residues that reside at the soil surface?" The present investigation was directed toward identifying the indigenous fungal flora on dead plants standing in fields, followed by a literature search relevant to questions of whether and under what circumstances such fungi might play a significant role in residue decomposition.

Marion E. Simpson, Paul B. Marsh, and Lawrence J. Sikora are all microbiologists in the Soil Microbial Systems Laboratory, U.S. Department of Agriculture, Beltsville, MD 20705.

Materials and methods

Leaves and stems of corn and other dead standing plants were collected from fields at Beltsville and elsewhere in the United States, beginning in the fall of 1984. Small pieces of tissue were planted on 2% water agar in Petri dishes, incubated for 2-4 days at 30 C, and then examined microscopically to observe characteristic fungal structures. This method was designed to detect fungi growing on the tissue at the time of collection and to avoid detection of chance air contaminants. It was similar to a method previously used by us with cotton fiber (Simpson and Marsh, 1983).

Results

Weather conditions

The samples examined had encountered quite different temperature and precipitation conditions during pre-collection weathering at the different stations. Monthly averages for maximum and minimum daily temperatures and for monthly precipitation in the period prior to sample collection are shown in

Table 1. Monthly average maximum and minimum daily temperatures in Centigrade degrees and precipitation in millimeters during the fall of 1984 and spring of 1985 at eight locations where collections of dead leaves and stems were made for fungal observations at Beltsville.

Location	Measurements during the months of: October	November	December	January	February	March	Date of sample collection
Beckley, WV							
Maximum temp.	22	11	11	3	5	13	3/31/85
Minimum temp.	11	−1	1	−9	−6	0	
Precipitation	55	105	89	78	65	67	
Beltsville, MD							
Maximum temp.	21	13	13	2	7	13	10/23/84
Minimum temp.	11	0	2	−7	−3	1	through
Precipitation	80	104	41	53	93	57	6/14/85
El Reno, OK							
Maximum temp.	—†	—	—	−4	2	15	5/19/85
Minimum temp.	—	—	—	−4	2	15	
Precipitation	—	—	—	10	86	66	
Florence, SC							
Maximum temp.	28	18	19	10	16	—	2/28/85
Minimum temp.	14	3	4	−3	1	—	
Precipitation	12	8	37	118	107	—	
Lincoln, NE							
Maximum temp.	17	11	4	−1	1	13	4/4/85
Minimum temp.	7	−1	−7	−10	−10	−1	
Precipitation	74	13	88	7	14	35	
Morris, MN							
Maximum temp.	14	4	−5	−9	−7	5	3/31/85
Minimum temp.	3	−6	−16	−20	−17	−4	
Precipitation	207	4	26	10	12	70	
Pullman, WA							
Maximum temp.	13	6	0	−2	1	8	3/31/85
Minimum temp.	1	1	−7	−1	−7	−3	
Precipitation	41	97	94	12	81	92	
Temple, TX							
Maximum temp.	25	19	18	11	14	21	3/22/85
Minimum temp.	20	9	8	0	4	13	
Precipitation	233	64	103	25	135	81	

† Dashes indicate data were unavailable.

Table 2. Microorganisms observed on dead leaves and stems of corn (*Zea mays*) collected following weathering of standing plants in fields at several U. S. locations.

Location	Plant part	Microorganisms: Actino-mycetes	Alter-naria	Clado-sporium herbarum	Fusarium spp	Fusarium monili-forme	Helmintho-sporium	Others
Beckley, WV	Leaf	x	x		x	x		
	Stem	x	x		x			
Beltsville, MD	Leaf	x	x	x	x	x	x	Colletotrichum,
	Stem	x	x		x	x	x	Diplodia, Epicoccum
El Reno, OK	Leaf		x	x			x	Chaetomium
	Stem	x	x		x			Chaetomium, Macrosporium
Florence, SC	Leaf	x	x		x		x	Curvularia
	Stem	x	x	x	x	x	x	Colletotrichum, Nigrospora
Lincoln, NE	Leaf		x	x	x			Aspergillus niger, Curvularia, Pullularia
	Stem	x	x	x	x			Aspergillus niger, Mucor, Nigrospora
Morris, MN	Leaf	x	x	x	x	x		Cephalosporium, Gliocladium, Rhizopus, Trichoderma
	Stem	x	x	x	x			Cephalosporium
Temple, TX	Leaf	x	x	x			x	Stemphylium
	Stem	x	x		x	x	x	

Table 1 for the several collection sites. Daily maximum and minimum temperatures were quite variable from one location to the next, while precipitation was highly variable from one location to another and from one time to another at single locations. Florence, S.C., and Temple, Tex., were warmer than other locations, while Morris, Minn., was cooler than others.

As a group, the temperatures recorded here in Table 1 were clearly much lower than those in a previous study in which cotton fiber was exposed to preharvest weathering in the U.S. Cotton Belt and then examined to detect fungi present by the same observational methods as those used in the present work. In the earlier work with cotton, average temperatures during exposure were in the range of 26-33 C (Simpson and Marsh, 1983). Comparisons of the fungal populations seen in the present work on various plants with those recorded earlier on field-weathered cotton fiber under warmer conditions will be made at a later point in the present paper.

Fungi on dead corn plants

Microscopic examinations of tissues from dead, weathered leaves and stems of corn *(Zea mays)* from Beltsville revealed spores, conidiophores, and/or other structures characteristic of *Alternaria* sp., *Cladosporium herbarum, Colletotrichum* sp., *Diplodia* sp., *Epicoccum* sp., *Fusarium* spp. (including *F. moniliforme),* and *Helminthosporium* sp., (Table 2). Pycnidia of *Diplodia* were seen clustered in a darkened area on the outer surface of the stem below the node. Growth of actinomycetes was observed on many samples. In addition, occasional but sparse growth of bacteria onto the water-agar was noted. Limited observations on leaves which had fallen to the soil surface suggested that leaves previously heavily colonized by field fungi were not readily invaded subsequently by soil fungi.

Dead, weathered corn leaves and stems from Beckley, W.Va., El Reno, Okla., Florence, S.C., Lincoln, Neb., Morris, Minn., and Temple, Tex., (Table 2) exhibited growths of many of the same field fungi seen on the corn samples from Beltsville. Certain fungi, i.e., *Al-*

ernaria sp., *Cladosporium herbarum, Fusarium* sp., and *Helminthosporium* sp. were observed on samples from all or almost all locations in spite of the rather large locational differences in temperature and precipitation recorded in Table 1. Some other fungi were also recorded (Table 2) but with lesser regularity. Fungal growth was often accompanied by darkening of the corn leaves and fibrillation, the latter situation involving vascular strands which remained intact after the interveinal tissue had been decomposed. Very little growth was seen of fungi from genera and species commonly and characteristically associated with humid storage (Christensen and Kaufmann, 1969; Magan and Lacey, 1984; Marsh and Bollenbacher, 1949) or soil situations (Gilman, 1957; Griffin, 1972; Parkinson and Waid, 1960) (aspergilli, penicillia, mucors, Stachybotrys, Humicola, Trichoderma).

Fungi on other dead field crop, garden, and native plants

Dead leaves and stems of wheat, sorghum and other plants from the several locations at which samples were collected frequently exhibited growths of many of the same field fungi observed on the corn samples (Table 3). Again there was very little growth of certain above-named types of fungi usually associated with storage or soil exposures. Fungal growth was almost always accompanied by visible growth of actinomycetes, sometimes luxuriant. Tables 2 and 3 show that all four of the fungus genera described by Christensen and Kaufmann (1969) as common "field fungi" in cereal grains (Alternaria, Cladosporium, Fusarium, and Helminthosporium) were also very common in our leaf and stem samples.

Fungi observed growing on Beltsville collections of several garden and native plants (Table 4) were generally field fungi of types noted commonly in the observations of Tables 2 and 3. These are clearly fungi especially adapted to the ecological niche they occupy. The most-frequently-present members (Tables 2, 3, and 4) consisted of Alternaria, *Cladosporium herbarum,* and *Fusarium* spp. Superimposed on this small core group were certain additional field fungi more specific to the individual sample or collection site.

Table 4. Microorganisms observed on dead leaves and stems of garden and native plants collected following weathering in fields near Beltsville, MD.

Kind of plant	Microorganisms: Alternaria	Cladosporium	Fusarium spp	Fusarium moniliforme	Others
Eggplant *Solanum melongena* L.	x	x	x		
Foxtail *Setaria* sp.		x			Cephalosporium, Epicoccum, Helminthosporium
Lima bean *Phaseolus lunatus* L.		x			Cephalosporium
Peas, black-eyed *Vigna unguiculata* L.	x				Actinomyces
Pepper *Capsicum annuum* L.	x		x		Cephalosporium
Pine (needles) *Pinus* sp.	x				Penicillium
Pokeweed *Phytolacca decandra* L.	x	x	x	x	Epicoccum, Gleosporium, Periconia
Ragweed *Ambrosia artemisiifolia* L.	x				Helminthosporium

Table 3. Microorganisms observed on dead leaves and stems of wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), and other field crop plants collected following weathering in fields at various U. S. locations.

Location	Plant	Plant part	Microorganisms: Actinomycetes	Alternaria	Cladosporium	Fusarium spp	Fusarium moniliforme	Helminthosporium	Others
El Reno, OK	Wheat	Leaf	x	x	x	x	x	x	Chaetomium
		Stem						x	Macrosporium
Florence, SC	Soybean	Leaf	x	x		x			Septonema, Periconia, Rhizoctonia
	Sunflower	Leaf	x	x	x				
Lincoln, NE	Sorghum	Leaf	x	x	x	x	x	x	Cephalosporium
		Stem	x	x		x	x		Cephalosporium
Morris, MN	Wheat	Leaf	x	x	x	x	x	x	
		Stem	x	x	x			x	Macrosporium, Stemphylium, Cephalosporium
Pullman, WS	Wheat	Leaf	x	x	x				Spicaria, Stemphylium, Trichoderma
		Stem	x	x	x				Macrosporium
Temple, TX	Sorghum	Leaf	x	x	x	x	x	x	Cephalosporium, Rhizoctonia
		Stem	x	x	x	x			
	Wheat	Leaf	x	x	x	x		x	

Discussion

Hudson (1971) has reviewed the literature on the kinds of fungi that grow most commonly on leaves as they senesce and fall; he called these fungi "common primary saprophytes." Included were *Cladosporium* spp., *Alternaria* spp., *Aureobasidium pullulans (Pullularia pullulans), Botrytis cinerea,* and several pycnidial and perithecial fungi. Host plants were *Fagus sylvatica* L. (beech) (Hogg and Hudson, 1966), *Typha latifolia* L. (cat-tail) (Pugh and Mulder, 1971), *Dactylis glomerata* L. (orchard grass), and *Saccharum officinarum* L. (sugar cane) (Hudson, 1962). Other English investigators reported finding the same limited group of fungi on senescent leaves of other plants (Brown, 1984; Dickinson and Preece, 1976; Preece and Dickinson, 1971; Tsuneda and Skoropad, 1978).

Some of Hudson's "common primary saprophytes" (Hudson, 1971) belong to genera which have been designated by others as "field fungi." In defining the latter term, Christensen and Kaufmann (1969) noted that species of Alternaria, Cladosporium, Helminthosporium, and

Fusarium are observed very frequently in field infections of seeds of wheat, rice, barley, and oats. Others have also observed infections with the same field fungi in seeds of cereals (Clarke and Hill, 1981; Ostazeski and Bever, 1955; Sauer et al., 1982) and dicots (Kremer, 1986). Many field fungi are pathogenic on senescent, weakened, or damaged plants and may persist into a saprophytic growth phase after the plant has died (Hooker, 1981; Mackenzie, 1981; Miller, 1983; Rotem, 1981; Zillinsky, 1983). We have reported that the field fungi Alternaria, *Cladosporium herbarum,* and Fusarium grow regularly in field-weathered cotton fiber from all parts of the U.S. Cotton Belt, a region generally much warmer than the areas involved in the present work (Marsh and Bollenbacher, 1949; Simpson and Marsh, 1983).

A literature search was made to locate reports with possible relevance to the potentiality of the fungi observed by us on dead standing plants for decomposing plant residues and the probable effect of environmental factors on the expression of this potentiality under field conditions. Many field fungi can decompose native cellulose and many soils fungi can also. Thus, data from the literature show that many isolates of the field fungi Alternaria, *Cladosporium herbarum*, Diplodia, Fusarium, and Helminthosporium were active in causing strength loss in cotton fabric, while isolates of Pullularia were not (Marsh et al., 1949). Some soils fungi, such as Gliocladium, Humicola, Stachybotrys, and Trichoderma, were also active in weakening cotton fabric, but others, such as some of the aspergilli, penicillia, and all mucoraceous fungi, were inactive.

Much additional information from culture tests on cotton fabric is in agreement with the information on cellulose decomposition just mentioned and has been cited previously (Marsh et al., 1949). The fact that the stalk-rot fungi Colletotrichum, Diplodia, and Fusarium cause visibly obvious physical disintegration and destruction of much stalk tissue in the standing corn plant (Shurtleff, 1980; Windels and Kommedahl, 1984) suggests that the same fungi may be active in the decomposition of residues.

No information seen in the literature suggests that the indigenous fungi detected by us on crop plants above ground can decompose lignin. Certain basidiomycetes are well known to decompose lignin but few if any other microorganisms are known to do so (Kirk et al., 1980). The fibrillation seen in many of the corn leaf samples, with greater resistance to degradation on the part of the cells in and around the vascular bundles, was in accord with these basic facts.

Leaf and stem waxes on residues might be used as a source of carbon by some fungi in nature, since pure-culture evidence shows that such use, including use by leaf-inhabiting fungi, is possible (Dickinson and MacNamara, 1983; Martin and Juniper, 1970). Such decomposition could perhaps decrease water repellence at plant surfaces and thus facilitate movement of water from the environment into a previously dried leaf or stem and thereby favor microbial decomposition of underlying cells.

Effects of differences in levels of oxygen, moisture, and temperature on field fungi and other fungi are suggested to be highly relevant to occurrence and rate of residue decomposition in field situations. From experiments on colonization of wheat straws in contact with soils by species of Helminthosporium, Ghurde (1966) concluded: "From the present studies it appears that the main factor influencing colonization is aeration." Parr and Reuszer (1959) observed that decomposition of wheat straw after 6 weeks with 5.0%, 2.5%, and 0% oxygen in the aerating gas was about 86%, 70%, and 13%, respectively, of what it was when the aerating gas contained 21% oxygen.

Moisture conditions in plant residues seem likely to be of great importance in many practical circumstances in determining the course and rate of their microbial decomposition. An ability to survive and grow in spite of the wetting-drying cycles which are such a prominent feature in the habitat for growth on dead leaves and on residues at the surface of the soil is probably a main element in the determination of which microorganisms grow commonly and cause decomposition in such situations (Diem, 1971). This characteristic, which occurs in field fungi (Diem, 1971), should not be confused with the xerophytic capabilities of fungi commonly found on organic material under continuous slightly damp storage condition as seen in the *Aspergillus glaucus, A. candidus,* and *A. versicolor* groups and some penicillia (Christensen and Kaufmann, 1969).

Temperature is an important determinant of the rate of growth of microorganisms, including field fungi, and probably influences rate of residue decomposition greatly. Fungi of genera listed here as "field fungi" generally show most rapid growth rates at or close to 25-28 C, with an upper limit for growth around 32-35 C, and with progressively slower rates at temperatures below and above the optimum (Allen et al., 1983; Chupp and Sherf, 1960; Coley-Smith et al., 1980; Hasija, 1970; Lauritzen, 1926; Magan and Lacey, 1984; Marsh and Simpson, 1976, 1982; Miller, 1983; Misra, 1973; Nelson et al., 1981; Shane et al., 1981; Susuri et al., 1982; Tint, 1945; Togashi, 1949; Tsuneda and Skoropad, 1978; Walker, 1969).

Many mesophilic fungi, including several field fungi, are known to be able to grow at temperatures near to 0 C (Brooks and Cooley, 1917, 1921; Cochrane, 1958; Frazier, 1958) but the rate of such growth is generally very much slower than at higher temperatures. A. Garroway and Evans (1984, p. 253) stated, "Although some fungi can survive in extremely cold environments growth at low temperatures is minimal for most fungi...." Examination of the temperature-growth data in the references cited in the paragraph just above reveals that rates of growth for mesophilic fungi in culture are usually very much less at 15 C than at 25 C and exhibit a major further decrease as the temperature is lowered again from 15 C to 5 C.

Temperatures recorded in Table 1 for sites from which we obtained weathered plant materials were clearly below or much below the optimum for growth of the indigenous fungi present. Certain fungi recorded here to grow commonly on dead corn, wheat, and other plants i.e., Alternaria, *Cladosporium herbarum,* and *Fusarium* spp., have also been observed to grow very commonly on field-weathered cotton in much warmer climates (Simpson and Marsh, 1983).

If residue decomposition slows greatly in the cold temperatures of mid-winter can field fungi survive cold winters and

esume growth promptly at a faster rate s temperatures increase in the spring? *Fusarium graminearum* can survive win-er exposures in corn stalks in Minnesota Windels and Kommedahl, 1984) and *F. noniliforme* in grain sorghum stalks Manzo and Claflin, 1984). Corn-infect-ng species of Colletotrichum, Diplodia, nd Helminthosporium can all overwin-er in tissues of the host plant (Shurtleff, 1980). Such results suggest that residue decomposition by field fungi probably can resume rather promptly with rising temperatures in the spring. Special sit-uations and special residue decomposers may occur on plants in continuously-cold climates. Much damage is caused to small-grain cereals by the psychro-philic pathogens *Fusarium nivale* and species of Typhula (Mathre, 1982; McBeath, 1985; Zillinsky, 1983), fungi known as "snow molds"; these fungi at-tack the living plant at low temperatures and may subsequently decompose resi-dues slowly at these temperatures.

The 50% loss in weight recorded by Parker (1962) for corn stalk residues in glass cloth bags placed on a soil surface in a corn field for 20 weeks during the corn-growing season in Iowa may have been caused by indigenous organisms of the types recorded here. Such experi-ments merit repetition and interpreta-tion in the light of the information here recorded, with specific identification of the organisms involved. Growth of some field fungi on cellulosic amendments to soils has been shown to improve gran-ulation characteristics of soils (Harris et al., 1966).

Conclusions

The indigenous above-ground micro-flora on dead standing plants has been shown to include a commonly-present core group of a few field fungi, some of them considered to have high resistance to the lethal effects of sunlight and wet-ting-drying cycles. Members of this group are proven decomposers of native cellulose and are believed to have the capacity to decompose cellulosic cell walls in residues. This conclusion is rein-forced by the fact that some of them cause conspicuous visible decomposition of parenchyma cells in some kinds of dead standing plants. In addition to sev-eral of the field fungi named here, many soils-inhabiting fungi also have a capa-bility for decomposition of native cel-lulose.

We suggest that structural decompo-sition by field fungi of residues placed at or on the soil surface is probably crit-ically dependent on adequate levels of oxygen and water and strongly governed in its rate by temperature. Additional studies are needed to characterize the rate and extent of decomposition of sur-face residues by indigenous microorga-nisms as they are affected by these and other variables. Such knowledge is es-pecially important in view of the strong trend toward conservation tillage sys-tems, since it could provide management strategies for controlling the decompo-sition of residues, i.e. accelerating their breakdown in cases in which residues are produced in excess and slowing their de-composition in residue-deficient areas for extended periods of soil protection.

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Altered Harvest: Agriculture, Genetics, and the Fate of the World's Food Supply. 1985. By Jack Doyle. 502 pp. Viking Penguin, Inc., New York, NY 10010. Cloth $25.00.

The last decade has witnessed a whole series of remarkable advances in genetics. Scientists have now cracked the gene as they have cracked the atom, and have obtained direct and unprecedentedly precise manipulative access to the basic and universal building blocks of life. With techniques such as recombinant DNA transfer and protoplast fusion, scientists now have the ability to override the limiting barrier of sexual compatibility: Genetic information can now be transferred *between* species as well as within species. Living organisms can now be genetically "engineered" in the strong sense of that word.

Outdoing evolution in this fashion is neither an end in itself nor a scientific game of genetic "button, button, who's got the button." Genetic engineering is an undertaking with far-reaching economic and social implications. The new "biotechnologies" promise to enhance significantly the power of the forces of production with which we create and reproduce the material conditions of our existence. The sectors upon which the new genetic technologies will have the greatest impact are fundamental components of the modern economy: Medicine, energy generation, pollution and waste management, chemical and pharmaceutical production, food processing, and of course, agricultural production.

It is to the consideration of the social and economic impacts of biotechnology in agriculture that Jack Doyle has turned his attention. If the revolution in biology is to result in an "altered harvest," then the fundamental questions become "how will the raw power in the food production process now made possible with genetic engineering be used? and who will use it?" (p. xix).

Doyle attempts to answer these questions in the 18 chapters which comprise the book. He is rather clear about who is best positioned to use the new power over food production which genetic engineering provides. Business interests were quick to perceive the commercial potential of biotechnology. It is the Monsantos, the Ciba-Geigys, the Shells, and the ARCOs of the world that are actively seeking (and according to Doyle achieving) a position of dominance vis a vis the new genetic technologies. This they are doing despite the appearance of entrepreneurial biotechnology "research boutiques." Large-scale capital is using its financial muscle to dominate, or absorb, these potential competitors. This financial muscle is also used to ensure that university-based science is directed into research which complements the interests of industry. Also, political muscle is deployed by business in order to move government agencies in desired directions in matters such as regulatory oversight and science policy.

Perhaps the greatest strength of Doyle's book is his recognition that the "who" part of his question is intimately linked to the "how." The tendency toward economic, political, and scientific concentration which he documents for the agricultural sector has important ramifications for the types of products likely to emerge from the research and development pipeline. For example, biotechnology offers the possibility of making real advances toward what Doyle calls an agricultural "soft path." Genetic engineering might be used to create new biorational pesticides or even crop varieties engineered to produce their own pesticides. But, given the pivotal position of petrochemical companies in the commercialization of biotechnology, will the soft path be taken if it means the displacement of chemical product lines?

The twin themes of *who* controls the development of new technology and *how* the new technologies are developed are articulated to a wide variety of important issues. Among those treated are genetic diversity and vulnerability, changes in farm structure, concentration in the seed industry, nutritional quality of food, the "chemical connection", animal biotechnology, university/industry relations, the prospect for a new biotechnology-based "Green Revolution" in the Third World, regulation of genetic engineering, and the possibility of negative ecological impacts resulting from the deliberate release of novel organisms. Indeed, there are few important issues which Doyle has not managed to weave into his story. And this is appropriate, for the new genetics does touch upon a multiplicity of areas.

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In his concluding chapter (Faust in the Wheatfield), Doyle suggests that the Faustean bargain struck by advanced capitalist societies on "the altar of high technology" in the 1930s is coming up for renegotiation. He asserts that the new genetic technologies "*can* be applied in a beneficial direction. All that is necessary is the institutional will and political force to move the system in the right direction" (p. 377). Unfortunately, he has little to say about the basis for or means of mobilizing such movement. That, however, is probably too much to ask. For the moment, it is enough that the problems and issues raised by Doyle are brought into the public eye. -- *Jack Kloppenburg, Jr., Assistant Professor of Rural Sociology, University of Wisconsin*

Eroding Soils: The Off-Farm Impacts. 1985. By Edwin H. Clark, II, Jennifer A. Haverkamp, and William Chapman. 252 pp. The Conservation Foundation, 1717 Massachusetts Ave., N.W., Washington, DC 20036. Paper $15.00.

This book may well contain the best collection of information available on the many faceted problems and impacts associated with water pollution from agricultural nonpoint-sources. Documented with an impressive number of sound references (about 137 references in each of the main chapters), the authors have gleaned, organized and presented in very readable form, vital material which further reinforces the need for attaining a sustainable agriculture.

Chapter 1 describes the magnitude of the problem, with particular reference to erosion rates and off-farm impacts. Chapter 2 provides a comprehensive review of the processes responsible for moving agricultural contaminants off-site. Chapters 3 and 4 describe the results of an extensive literature search for documentation of the range, extent, and seriousness of off-site impacts. Chapter 5 delves into economic costs and Chapter 6 summarizes current knowledge of the techniques for achieving improved agricultural nonpoint-source pollution control. The final chapter explores policy options and suggests some implementation strategies.

Although the authors estimate the annual off-farm costs of agricultural nonpoint-source pollution to be in the neighborhood of $6 billion, and bolster their argument with compelling physical, biological, technical, and economic facts related to in-stream and off-stream impacts, they do not solve the policy hurdle. Some policy options are suggested in the last chapter, turning largely on the concept of targeting, coupled with mechanisms such as soil-loss tax, zoning to restrict certain agricultural uses or practices, enforceable contracts and public purchase. But implementation of these policies is left largely to the reader's imagination or the next publication of The Conservation Foundation.

The challenge is clearly summarized in the last paragraph of the book: "In short, the question is not whether an effective program to control the off-farm impacts of soil erosion is possible. Rather, the question is whether U.S. society has the will."

One topic treated too lightly in the opinion of this reviewer is contamination of groundwater by agriculture. Growing evidence suggests that groundwater contamination from agricultural chemicals may be more wide spread than originally thought. If this is true, then it is likely that off-farm impacts of agricultural contaminants may be even greater than those estimated by the authors.

This book is not The Conservation Foundation's first on this subject. Publications preceding this one include *The Future of American Agriculture as a Strategic Resource* (1980), *Soil Erosion: Crisis in America's Cropland?* (1983), and *State of the Environment: An Assessment at Mid-Decade* (1984).

Eroding Soils: The Off-Farm Impacts is a useful addition to the library of all agriculturalists, policymakers, environmentalists, and those involved in soil and water management. It is written in a clear and interesting style, making it quite suitable for the lay reader and those involved with environmental education. -- *Eckhart Dersch, Professor and Extension Specialist in Soil and Water Conservation, Department of Resource Development, Michigan State University*

UPCOMING EVENTS

June 25-26. Alternative Farming Field Day at North Carolina State University at Raleigh. Contact Department of Soil Science, P.O. Box 7619, Raleigh, NC 27695.

Aug. 3-6. Annual Meeting of Soil Conservation Society of America at Winston-Salem, N.C. Contact SCSA at 7515 N.E. Ankeny Road, Ankeny, IA 50021.

Aug. 8-10. International Permaculture Conference at Evergreen State College at Olympia, Wash. Contact Permaculture Institute of North America, 6488 Maxwelton Road, Clinton, WA 98236.

Aug. 10-16. Fourth International Congress of Ecology at Syracuse, N.Y. Contact College of Environmental Science and Forestry, State University of New York, Syracuse, NY 13210.

Aug. 18-21. Sixth International Scientific Conference of the International Federation of Organic Agriculture Movements at the University of California at Santa Cruz. Contact Agroecology Program, University of California, Santa Cruz, CA 95064.

Sept. 5-6. Third Annual Field Days sponsored by Regenerative Agriculture Association and Thompson's On-Farm Research. Contact Dick and Sharon Thompson, R.R. 2, Box 132, Boone, IA 50036.

Sept. 19-21. Tenth Annual Common Ground Country Fair sponsored by the Maine Organic Farmers and Gardeners Association at Windsor, Maine. Contact MOFGA at P.O. Box 2176, Augusta, ME 04330.

Nov. 20-21. National Conference on Sustaining Agriculture Near Cities in Boston. Contact William Lockeretz, School of Nutrition, Tufts University, Medford, MA 02155.

OTA report assesses impact of emerging technologies on agriculture

A report prepared by the Congressional Office of Technology Assessment (OTA) concludes that American agriculture is being propelled into a biotechnology and information technology era that will produce scientific advances that significantly increase yields and substantially reduce the number of farms.

"The immediate impact of these technologies will be felt first in animal production through embryo transfers, gene insertion, growth hormones, and other genetic engineering techniques," the report concludes. "Impacts on plant production will take longer, almost the remainder of the century. By that time, however, technical advances will allow some major crops to be altered genetically for disease and insect resistance, higher production of protein, and self-production of fertilizer and herbicide."

Although most news reports focused on a projection that as many as 1 million farms may be swept away over the next 15 years by this wave of new technology, the report itself is a comprehensive and systematic analysis of the likely impacts of technology on agriculture between now and the year 2000. It focuses on the relationship of technology to production, farm structure, rural communities, resource conservation, credit, research and extension, and public policy.

The 374-page report concludes that these new technologies will have an enormous impact on the structure of agriculture and the rural communities that support farming. It predicts that most of the benefits of this new technology will accrue to 50,000 huge farms that will produce most of the nation's food and fiber. "The moderate-size farm will largely be eliminated as a viable force in American agriculture," it said.

Emerging technologies

The report identifies and describes 150 production technologies likely to be available commercially to shape and define agriculture to the year 2000. They include the use of computer and electronic technologies for the automated collection, manipulation, and processing of information related to areas like irrigation, pest management, and application of farm chemicals.

Although most of the report is devoted to analyses of these and other emerging areas of high technology, nonetheless it does describe organic farming as an important and beneficial farm management system. It points out, for example, that organic farms use crop rotations and residues to help control weeds, appear to cycle nutrients more efficiently than conventional systems do, and significantly reduce soil erosion. "Furthermore some organic practices enhance the soil's ability to suppress disease," the report stated. "Scientists hope to identify the helpful bacteria and bacterial byproducts involved in disease resistance and to harness them as biocontrol agents."

The report suggested that advances such as biological pest repellants, biological nitrogen fixation, and improved crop rotations would enhance the outlook for production systems that avoid chemicals. It also touched on the problem of reduced yields during a conversion from conventional to organic methods and said this relates to the availability of soil nitrogen and to weed pressure.

Farming systems studies

The report called for detailed studies of holistic systems to better understand complex changes in nutrient flows in soils under organic and conventional management systems. "The potential impact of such studies on U.S. agriculture in the next 10 years could be considerable," it noted. "If farmers shifted to organic production, farms would be more diverse biologically and economically, and the small farm could remain economically competitive and ensure diverse, competitive food production systems."

Despite the acknowledged benefits of alternative farming systems, the assessment panel expressed skepticism about the extent to which organic farming techniques would be adopted. "If energy prices rise substantially, organic farming techniques might be adopted rather widely," the report concluded.

Widespread adoption of organic systems, it said, could have adverse impacts on environmental resources. These undesirable impacts were identified as increased pressure on marginal and erodible lands, more production on land now used as wildlife habitat, and water and air pollution caused by increased use of manure. "Perhaps the strongest positive impact was thought to be in the area of human health," the report said. "Organic farming would reduce human exposure to agricultural chemicals and could result in food products that have higher nutritional values and less chemical contamination."

This March, 1986, report should be thoughtfully and thoroughly examined. While it is too early to judge the impact of the report, its projections pose troubling questions for those who support a viable system of mid-sized family farms. There is still time to develop the science and technology of sustainable, low-input, biologically-based farming systems and make these productive, yet less costly, technologies more widely available. There is also ample evidence that a significant proportion of agriculturalists and consumers see merit in pursuing these low-input technologies. The character of American agriculture in the year 2000 will depend far more on decisions made between now and then on technology choices than it will on the projections in this comprehensive, objective, yet disturbing, OTA report.

Guide for authors

AJAA will publish original research on biological, physical, social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from specific discipline also are invited. However, since AJAA adership is much broader than for a single-discipline journal, ghly specialized terminology should be explained or avoided. ne significance of a statement, or the reasoning behind a nclusion, may have to be spelled out more than in a more ecialized journal. Research papers usually should be no nger than about 20 double-spaced pages.

omenclature and technical details

Research papers should use the International (SI, or metric) stem throughout. Write out "liters". "Metric ton", although ot strictly an accepted SI unit, can be used for data referring "ordinary life," such as national crop output, as opposed experimental data. Occasional use of common unit equivents in parentheses is permitted, mainly for relatively exotic units.

The binominal or trinominal designation of a plant or anal species, and the cultivar where relevant, should be given parentheses the first time the common name of the species mentioned. Either name may be used thereafter. The same plies to names of chemicals that have both a common name nd a chemical name. Do not use brand names except where ne chemical is produced under a unique brand name. In those ases the brand name, identified as such, may be given the rst time the chemical is mentioned. Nutrient applications ould be given in elemental form (N,P,K). Oxide forms can e used in describing commercial fertilizers.

itle page

The title page should give the following information (all ush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgeents, if any. See examples in this issue of AJAA.

bstract

The abstract should be 200 to 400 words suitable for readers om a broad range of disciplines. It should avoid highly-ecialized terminology that might be appropriate for a single iscipline journal. Take particular care that the significance f the work is made clear, even to readers from a different eld.

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References should be listed in alphabetical order by author's ame, and by year for a particular author (with letters after ne year if needed). If a sole author is also the lead author of apers with multiple authors, use the following order: single uthor (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word. Do not underline anything except species names.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization set up in 1983 to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

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